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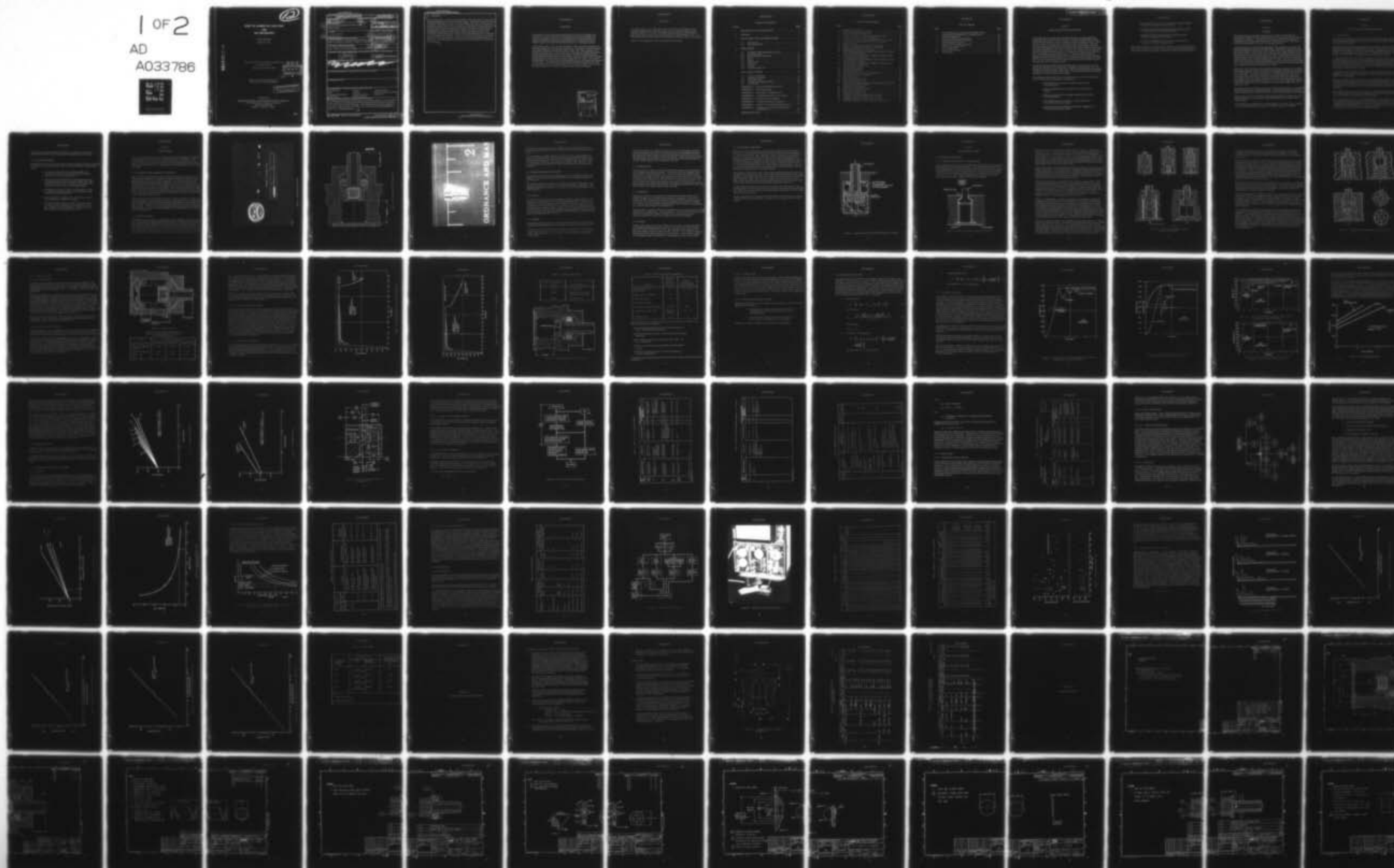

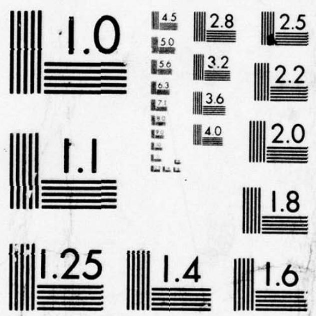

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STUDY OF DAMPED SET–BACK PINS
FOR
S&A MECHANISMS

FINAL REPORT

November 1976

Fuze Development and Engineering Division

Picatinny Arsenal

Dover, New Jersey 07801

Contract No. DAAA21-75-C-0179
DA Project No. 1W662616AH77

Prepared by

AEROJET ORDNANCE AND MANUFACTURING COMPANY
A Division of Aerojet-General Corporation
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Downey, California 90241

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
14 1938-~~00~~(~~0~~1)FP

2. GOVT ACCESSION NO.
and

3. RECIPIENT'S CATALOG NUMBER
9

4. TITLE (and Subtitle)
6 Study of Damped Set-Back Pins for S&A Mechanisms,

5. TYPE OF REPORT & PERIOD COVERED
Final Report.
Feb 1975 ~~through~~-March 1976,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
10 H. H./Furuike

8. CONTRACT OR GRANT NUMBER(s)
15 DAAA21-75-C-0179 New

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Aerojet Ordnance & Manufacturing Company
9236 E. Hall Road, Downey, California 90241

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
16 1W662616AH77

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army, Picatinny Arsenal
Dover, New Jersey 07801 SARPA-AD-F-D

12. REPORT DATE
11 November 1976

13. NUMBER OF PAGES
140

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
12 141p.

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
[redacted]

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Set-back Pin	O-ring	Teflon O-ring
S&A	Bellows	Porous sintered metal disc
Computer Simulation	Long tube orifice	Flow rate
Math Model	Porous Plastic	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The damped set-back pin study program was for the design, testing, fabrication, and delivery of damped set-back pin assemblies for use in a safe and arm device for artillery munitions. This damped set-back pin assembly is one of two safety features on a S&A device used in the M739 PD/XM587 ET fuzes for a rotating projectile.

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20 ABSTRACT

A pin, porous disc, return spring, floating O-ring, and sleeve comprise the selected damped set-back pin assembly design. Damping is acquired through the proper regulation and control of the air flow rate, return spring force, and the O-ring friction. Tests conducted to determine the design parameters and the structural integrity of the pin system included O-ring/lubrication compatibility testing, O-ring friction testing, flow rate measurements through porous sintered metal discs, and selected MIL-STD-331 tests. Two minor modifications were made to the existing bottom plate to incorporate the damped set-back pin -- the boss (closure disc end) that housed the present set-back pin assembly was removed and Emralon lubrication was added. All test and analysis results proved that the floating O-ring concept is feasible.

ABSTRACT

The damped set-back pin study program was to assist in the design, and evaluation of damped set-back pin assemblies for use in a safe and arm device for artillery munitions. This damped set-back pin assembly is a potential candidate for one of two safety features on a S&A device which could be used in the M739 PD/XM587 ET fuzes for a rotating projectile.

A pin, porous disc, return spring, floating O-ring, and sleeve comprise the selected damped set-back pin assembly design. Damping is acquired through the proper regulation and control of the air flow rate, return spring force, and the O-ring friction. Tests conducted to determine the design parameters and the structural integrity of the pin system included O-ring/lubrication compatibility testing, O-ring friction testing, flow rate measurements through porous sintered metal discs, and selected MIL-STD-331 tests. Two minor modifications were made to the existing bottom plate to incorporate the damped set-back pin -- the boss (closure disc end) that housed the present set-back pin assembly was removed and Emralon lubrication was added. All test and analysis results proved that the floating O-ring concept is feasible.

FOREWORD

This final report is submitted by the Aerojet Ordnance and Manufacturing Company (AOMC), 9236 East Hall Road, Downey, California 90241, under Contract DAAA21-75-C-0179. TheAOMC report number is 1938-00(01)FP. This report covers the period from February 1975 through March 1976. The Project Manager was Mr. Lloyd Post of Picatinny Arsenal, Dover, New Jersey.

This work was supported by the Army Materiel Command.

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Section 1

INTRODUCTION AND BACKGROUND

At one point in the development of the M739 PD fuze an unanticipated and abnormally high dud rate of approximately 7 to 20% was experienced during 155mm M114A1 Howitzer Zone 1 (minimum setback condition) and 8-in. M110 Howitzer Zone 1 (minimum sprin condition) service test firings. This dud rate was traced to a malfunction of the S&A module set-back pin assembly. An analytical diagnostic approach by Picatinny and others consisted of a lumped parameter (equivalent spring-mass system) of the round and fuze components for axial component motion as well as a study of the dynamics of various set-back pin designs during the firing cycle. Evaluation of test results and analytical programs indicated the problem to be due to the set-back pin reengaging the rotor under the influence of a combination of CG location of the pin, low "G" short pulse duration environment during the launch, elastic rebound and balloting, thus preventing arming.

Because of the great difficulty of characterizing some of the more unusual inbore environments such as balloting, chuggings, corkscrewing, ect., and designing a set-back system whose action was delayed during this phenomenon, thereby not jeopardizing the arming cycle. Such an approach offered potenial advantage over the actual solution adopted.

The program requirements were to provide the Army with the following features: (see detailed requirements in Appendix A)

- Returnable set-back pin for increased safety during normal handling.
- High reliability similar to that of the one-way lock-out design.
- Pin fit within diameter and length constraints of the S&A for the M739 fuze.
- Pin withdrawal not to exceed 5 to 7 msec and pin not to interfere with rotor arming.
- Pin not be adversely affected by balloting, chugging, etc. during internal ballistic phase.

- Pin operable in all zones or all artillery weapons (including 4.2 in.) between -40° and +145°F.

- Pass test requirements of jolt, jumble, 40-ft drop, and transportation vibration of MIL-STD-331.

- Capable of being mathematically modeled to predict behavior during dynamic response.

- Provide drawing package of final design (the drawing package is included as Appendix B).

This report presents the results of the work done under Contract DAAA21-75-C-0179 to evaluate a damped set-back pin utilizing a floating O-ring seal and sintered metal porous plug to control the motion of the set-back pin.

Section 2

SUMMARY

The damped set-back pin study program was to assist in the design and evaluation of damped set-back pin assemblies for use in a safe and arm device for artillery munitions. This damped set-back pin assembly is a potential candidate for one of two safety features on a S&A device which could be used in the M739 PD/XM587 ET fuzes for a rotating projectile.

A pin, porous disc, return spring, floating O-ring, and sleeve comprise the selected damped set-back pin assembly design. Damping is acquired through the proper regulation and control of the air flow rate, return spring force, and the O-ring friction. Tests conducted to determine the design parameters and the structural integrity of the pin system included O-ring/lubrication compatibility testing, O-ring friction testing, flow rate measurements through porous sintered metal discs, and selected MIL-STD-331 tests. Two minor modifications were made to the existing bottom plate to incorporate the damped set-back pin -- the boss (closure disc end) that housed the present set-back pin assembly was removed and Emralon lubrication was added.

Delay time tests conducted on the damped set-back pins indicate that a skewed distribution exists at the three temperature conditions investigated. The times favor long delay time, which is favorable in the application of the damped set-back pin design. A graphic representation on log-normal paper showed the percentage of S&A device that will have a particular delay time band width. An average of 89.23% of all the damped set-back pin assemblies (S&A device) tested had a delay time width of 80 msec to 1.0 sec prior to MIL-STD testing. Post tests showed 87.3% of the damped set-back pins had a delay band of 80 msec to 1.0 sec.

The delay times were obtained using porous disc density of 72% of the material's theoretical density and a 300g bias spring. Computer simulation showed that the pin response time is less than 5 msec, which meets the design requirements.

Based on all tests of the assembly, the damped set-back pin system has shown that the floating O-ring concept can effectively delay the pin motion on the return stroke.

The reliability of the S&A device was determined to be 0.9957 when a reliability of 1.0 was assumed for the spin, acceleration, and rotor assembly.

Section 3

CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

Of the several concepts for retarding set-back pin return motion studied, the air damped approach utilizing a returnable pin, floating O-ring, and porous disc proved most feasible.

A system having a bias of 300g responsive to a change in velocity (Δv) of approximately 12 fps was successfully evaluated. Although this is less than the desired goal (500g and 200 fps) it represents a marked improvement in safety over the existing set-back pin system in the M739 Fuze which biased at 30g. The reliability of the system was predicated to be 0.9957.

A mathematical model of the dynamic response of the damped set-back pin has been successfully modeled and a computer program written. The computer program showed that the damped set-back pin is capable of functioning in the set-back and spin environment of an artillery projectile and that it does meet the required withdrawal time of 5 to 7 msec and can provide a nominal delay of at least 0.2 sec in the size studied.

Safety analysis indicated that selected projectiles may present a hazard when exposed to a ramp-roll/impact situation. These included the 155mm, 175mm, and the 8-in. projectiles.

Several variations of the basic system were evaluated and discarded either for technical or cost considerations. These included use of a bellows, replacement of restrictor with an orifice, teflon O-ring, and controlled O-ring friction. The use of a porous plastic material showed promise for replacing the sintered restrictor.

The mean delay time is 250 msec at ambient. Test results of 50 units appear to be considerably skewed to the long delay side which is favorable from the returned pin affect on reliability of rotor operation.

The nominal delay time to be eventually selected will of necessity be a compromise based on safety and reliability considerations. For greatest reliability it should not be less than about 700 msec; for greatest safety it should not exceed about 130 msec (assuming a ramp-roll situation). It must always exceed 80 msec in order to avoid a resafing condition.

The cost of this type of damped set-back pin is predicted to cost in full production about 3 times the existing M739 pin system. ($.36 vs $.12)

3.2 RECOMMENDATIONS

Although the damped set-back pin system appears feasible, further study should be conducted on the safety aspect of the overall S&A concept. These areas include

a. Increase pin dependency for withfrawal on ΔV so it will withdraw under actual launch only (discriminate between G-T of drop versus launch).

b. Increase pin delay dependency of centrifugal force (and resultant friction), so delay would be longer under 3000 rpm than under 1300 rpm. Therefore, pin would return much sooner under ramp-roll than under firing.

c. Change pin material to a higher yield strength in order to withstand the 80-lb transverse load required by MIL-F-48277 for the M739 PD fuze.

d. Conduct ballistic evaluation of the set-back pin system when adapted to the M739 S&A module.

e. The porous plastic restrictor should be further studied to determine the feasibility of this material as an air flow regulator from the standpoint of reliability of operation, simplicity, producibility, and cost.

Section 4

FINAL DESIGN

The set-back pin is one of two mechanical locks (the other being spin detents) that prevents the S&A rotor from rotating during normal handling. This is accomplished by the insertion of the set-back pin into a cavity in the rotor section. Figure 1 shows an exploded view of the set-back pin system with the bottom plate of the S&A device. Appendix C discusses the description of manufacturing.

4.1 FLOATING O-RING DAMPED SET-BACK PIN

Figure 2 shows the damped set-back pin design evaluated during this study. This design incorporates a "floating" O-ring seal, a porous, sintered metal plug, a sleeve, and a set-back/return spring. For proper functioning, the floating O-ring fits loosely within the gland groove in the set-back pin, but has an interference fit of a few thousandths of an inch with the bore of the set-back pin cavity. This allows air to escape when the pin is retracted and seals when the pin returns to its normal position. The sintered metal plug is on the bottom of the pin and acts as a throttling device to restrict and control the flow of air. Control of air flow into and out of the sealed cavity below the set-back pin provides the damping function.

The pin is made from a stainless steel alloy. Experimental stress analysis test indicates that a 303Se stainless steel pin will deform under an 80-lb transverse load (Figure 3 shows the deformed pin) when applied in accordance with MIL-F-48277. Although the pin is deformed the S&A rotor is still considered safe to handle. However, future pins should be fabricated and tested using 416 stainless steel for improving yield strength (YS of 303Se=40,000 psi versus YS of 416 = 110,000 psi).

4.2 FLOATING O-RING

The floating O-ring is used as a check valve for the damped set-back pin system. When the pin is being retracted under dynamic conditions the O-ring is picked up by the upper flange of the pin, allowing air to escape around the inside diameter of the O-ring and through the vent slots in the upper flange. Then, after the set-back environment decays, the return spring forces the pin to the normally extended position. As the pin moves out, the O-ring comes in contact with the lower flange of the set-back pin, which then acquires a seal.

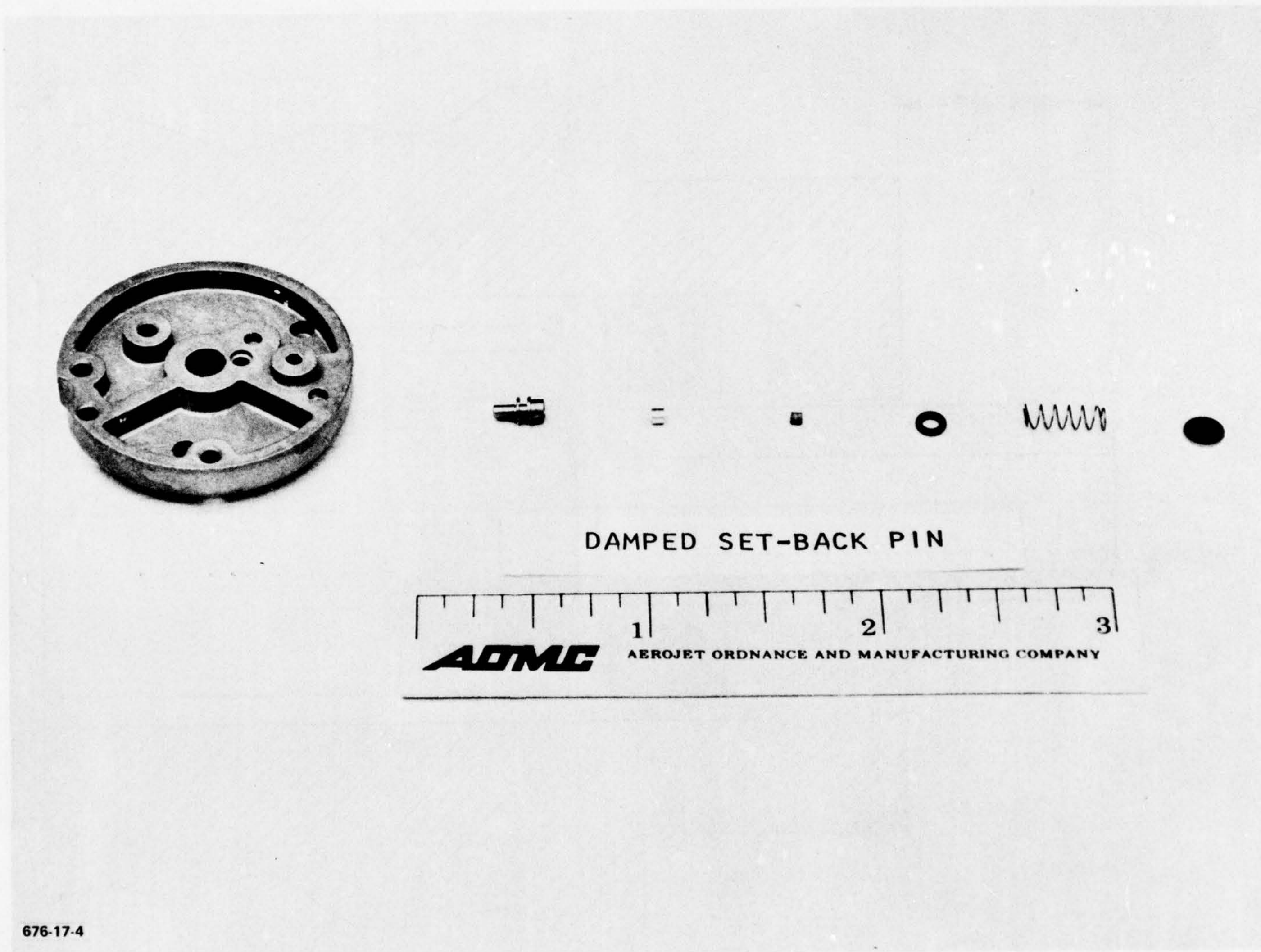

Figure 1. Damped Set-Back Pin.

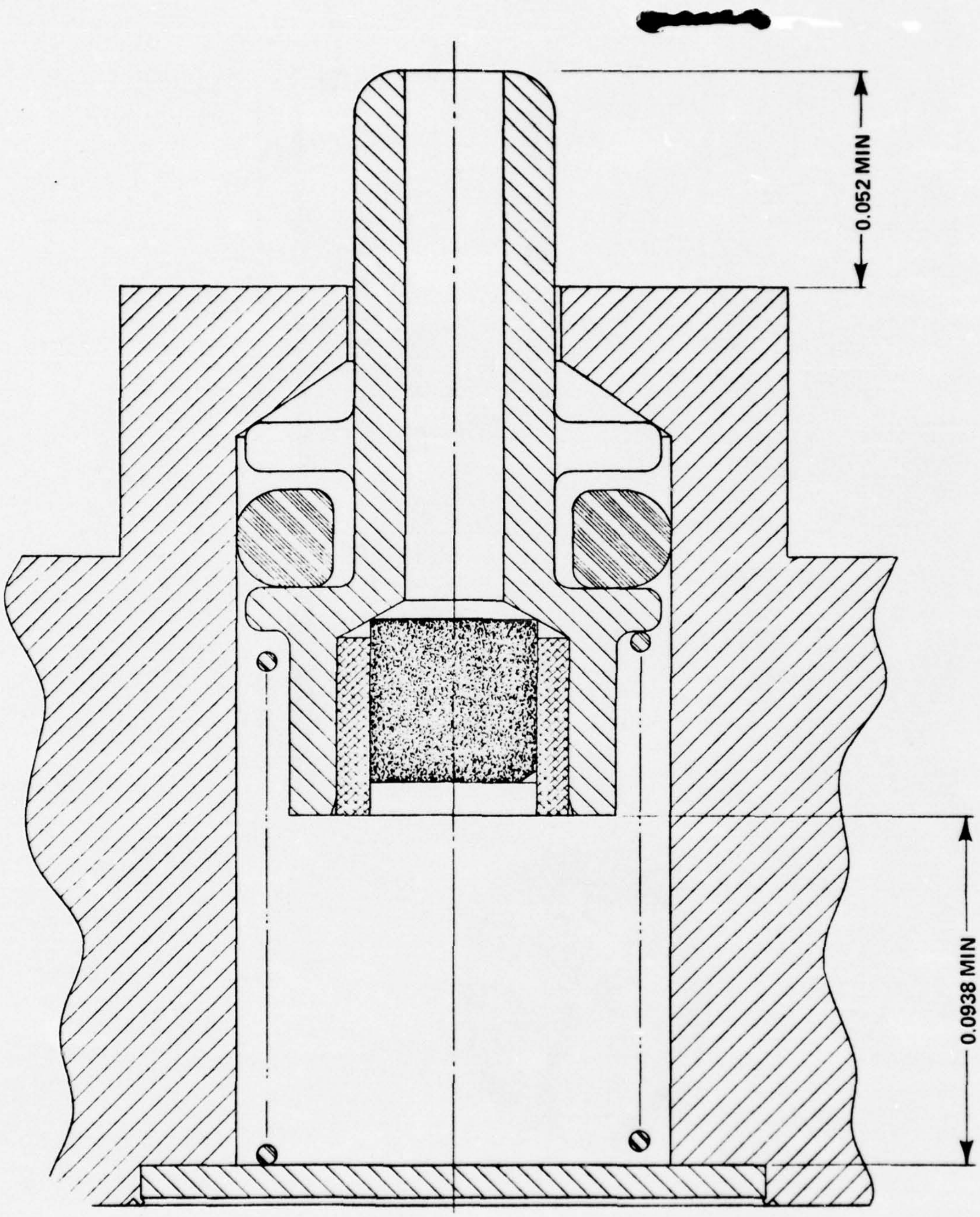

Figure 2. Damped Set-Back Pin Assembly.

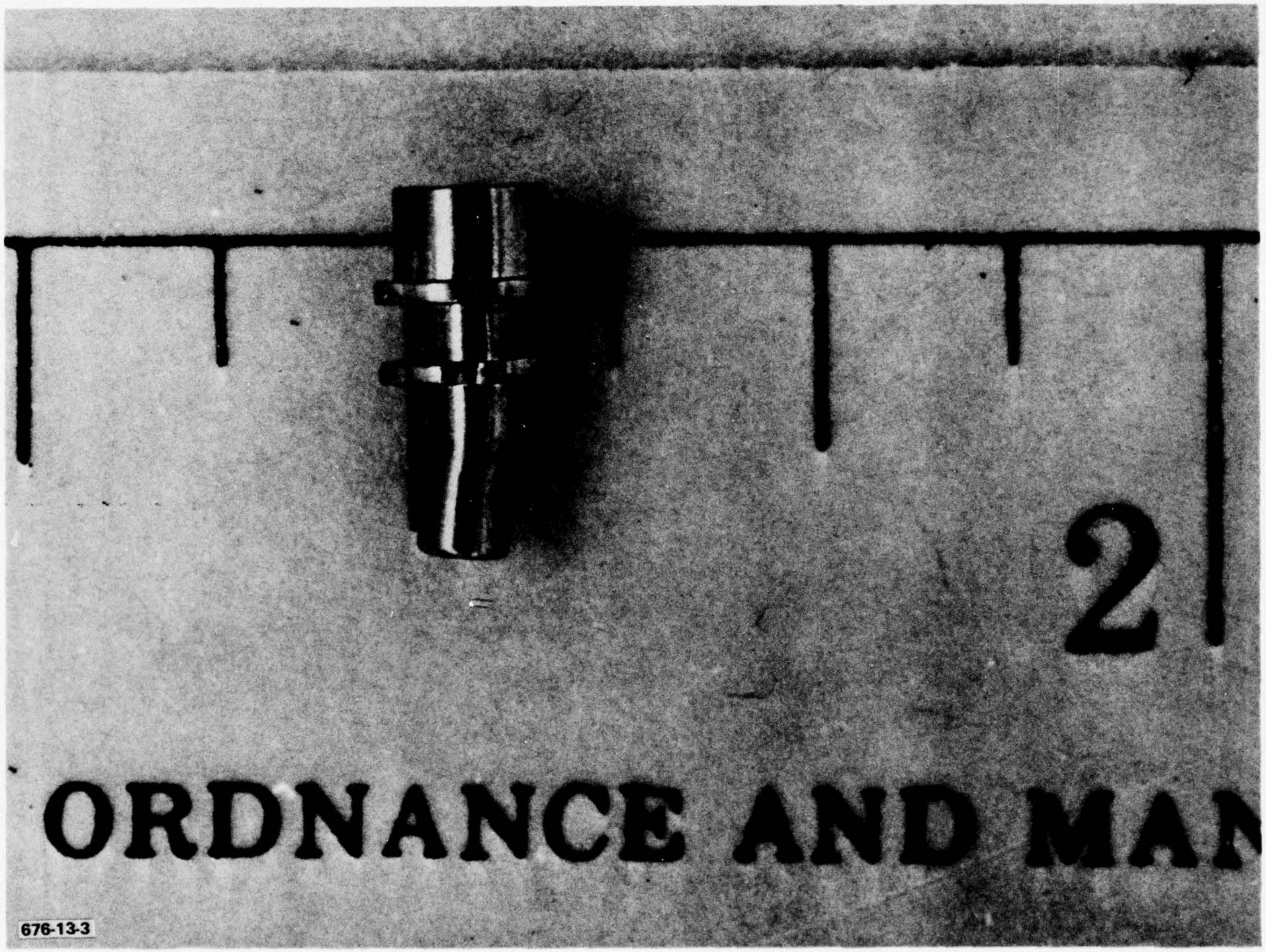

Figure 3. Deformed Damped Set-Back Pin.

It should be noted that the O-ring is always in an interference fit with the O-ring outside diameter and the bore of the cavity in which the pin assembly is in.

The O-ring has an outside diameter of 0.138 -0.003 in. and a gland cross-section of 0.030 ±0.002 in. and uses a silicone compound with a shore "A" durameter hardness of 50. The O-ring is designed with a "D" cross section to increase the reliability of sealing between rubber, pin, and wall. This is accomplished by relocating the mold line flashes away from the sealing surfaces.

4.3 POROUS SINTERED METAL DISC

The porous disc is used as a throttling device for the damped set-back pin system. It is this item that controls the flow of air to obtain a delaying motion of the pin.

The porous sintered metal disc is made from 100 mesh 316 stainless steel powder compressed to a 0.050-in.-diameter by 0.050-in.-long pellet. The resultant density is 0.2047 lb/cu in., which is 72% of the theoretical density of the material.

4.4 SLEEVE

The sleeve is used to prevent air leakage around the outside diameter of the porous disc created from an oval or truncated shaped disc. This sleeve is made from 1100-0 aluminum and is inserted between the counterbore in the pin and the porous disc (Figure 2). To obtain an effective seal, the sleeve is deformed or, actually, allowed to form a gasket in the cavity by taking the form of the disc and cavity when assembly force is applied to the sleeve end. This sleeve/disc arrangement is capable of withstanding over 349,000g loads before being dislodged from its seat.

4.5 SPRING

The purpose of the spring is to return the pin assembly to the safe position (extended position) following an accidental base-down drop of the projectile.

The primary design criteria of the spring was based on the minimum force required by the spring to overcome the maximum resistive force that this spring might experience. The resistive force considered was that of the O-ring drag.

The spring design was a 300g level bias force. With this spring, sufficient force is available to prevent pin withdrawal under rough handling situations and return the damped set-back pin to the safe position after the delay time. The delay time of the damped set-back pin system is such that the rotor assembly has enough time to rotate to the armed position without being stopped by the side loading applied by the damped set-back pin.

4.6 CLOSURE DISC

The closure disc is used to provide an end cap and seal for the entrapped air for the damped set-back pin system. The closure disc was originally made from 0.020-in.-thick aluminum alloy. But, the closure disc thickness and material was changed to obtain maximum pin travel without a major redesign of portions of the S&A device. The closure disc is now 0.010-in.-thick stainless steel, thus gaining an additional 0.010-in. travel in pin movement. A stress analysis was performed to determine whether the closure disc is structurally sound in the high-g environment. The analysis results showd that a margin of safety of 31% exists based on yield strength.

4.7 LUBRICANT

Lubrication is used to minimize the O-ring friction drag and provide for a uniform friction force throughout the temperature extremes. Vydax 525, Braycote 650AC, Braycote 668, Silicone grease DC55M, Silicone grease DC 33, Emralon 312 and Emralon 330 were investigated to find the best suited lubrication (confirmed through compatibility and friction testing, see Appendix D). The lubricant selected was Emralon 330.

Emralon 330 is currently used on the escapement portion of the S&A that is being considered for modification. This lubrication is a resin-bonded PTFE lubricant. Only an extremely thin coating of Emralon 330 is necessary to achieve maximun lubrication, which can be applied by spraying or dipping.

4.8 SEALING

Sealing of the closure disc must be effective to produce a reliable operation. Air leakage passing through the interface of the closure disc and the bottom plate will cause a reduced delay time. The sealing was accomplished with structural adhesive/sealant, MIL-A-82484, Type III. This sealant is applied after the placement and crimping of the closure disc. This method of assembly eliminates sealant contamination to the damped set-back pin assembly.

4.9 FUNCTIONAL SEQUENCE

When the set-back environment is imposed on the system the set-back pin starts to move toward the bottom of the closed cavity, thereby compressing the compression spring. The "floating" O-ring, because of its interference fit in the cavity bore, remains stationary until it is picked up and carried along by the upper flange on the set-back pin (as shown schematically in the left half of Figure 4). When this occurs, the air trapped beneath the set-back pin escapes past the periphery of the lower flange, around the inside of the O-ring, and then through slots in the upper flange to the atmosphere. (Some air can also escape through the porous plug and up through the hole in the set-back pin, but this will be a very small amount.)

At the bottom of the stroke, after decay of the set-back environment, the compressed return spring forces the set-back pin toward the open end of the cavity (as shown in the right half of Figure 4). Again, the O-ring remains stationary until it comes in contact with the lower flange of the set-back pin. At this point, the O-ring becomes an effective seal against the bore of the cavity and at its contact point with the lower flange (see right half of Figure 4).

Further upward movement of the set-back pin will then create less air pressure below the set-back pin than above it so that air will then flow down through the center hole in the set-back pin and then through the porous, sintered metal plug into the cavity below.

Proper design of the O-ring and its frictional drag, the return spring, weight of pin and the sintered metal plug, controls the time required for the return stroke.

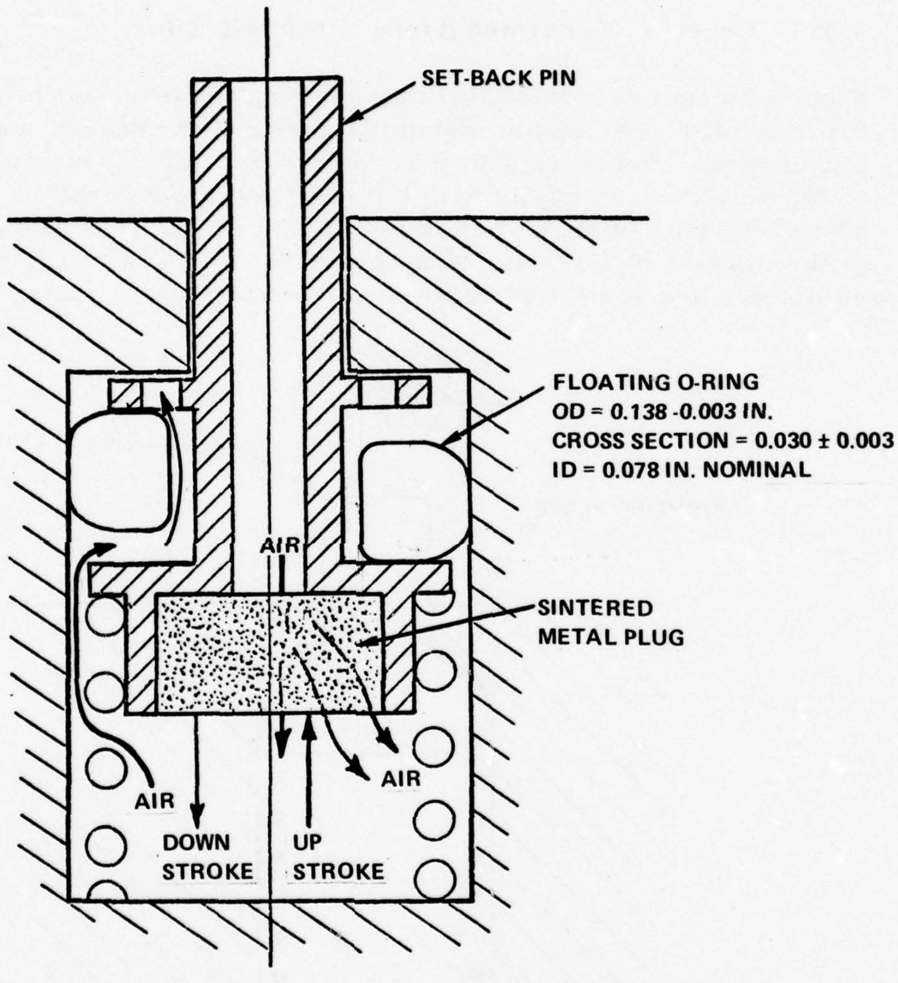

Figure 4. Damped Set-Back Pin Functional Sequence Design.

Section 5

ANALYTICAL STUDIES

5.1 REVIEW OF CONCEPTS

5.1.1 Concepts Generated during Proposal Effort

Eight concepts generated by others during the proposal effort were reviewed for feasibility and useful design features. The present design of the M739 set-back pin system is shown in Figure 5, which shows two cut-away views of the set-back pin cavity with the set-back pin and return spring installed. The lower part of the figure is drawn at 10 to 1 scale while the small inset at the top is 1 to 1 scale. With this perspective in mind, the following comments are submitted relative to the various concepts.

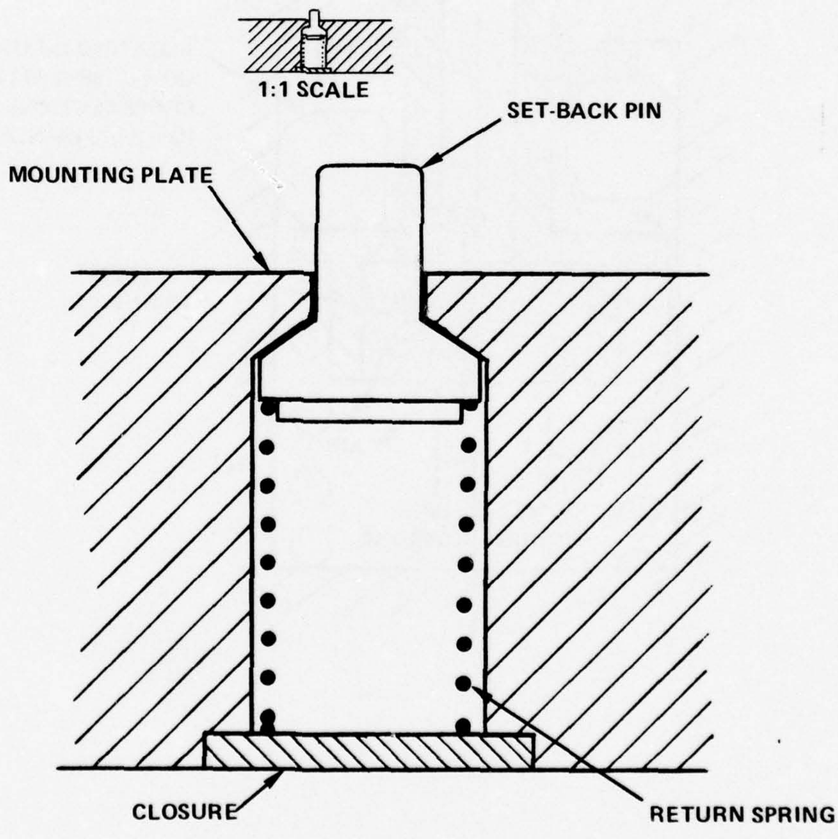

Figure 5. Cutaway of M739 Set-Back Pin Assembly

Figure 6 shows five of the eight initially proposed concepts. Figure 6 (a) represents a sharp-edged annular orifice dashpot design utilizing acetone as the damping fluid. This design appeared to have three major drawbacks: (1) the difficulty of satisfactorily sealing and containing highly volatile acetone under long-term storage conditions; (2) long-term degradation of the O-ring from contact with acetone (swelling), which would significantly alter the performance of the system; and (3) maintaining manufacturing tolerances on the sharp-edged orifice on the rim of the piston.

Figure 6 (b) utilizes an acme threaded jack-screw design to control the motion of the set-back pin. It was questionable whether the manufacturing tolerances on the components of this design could be controlled enough to yield reproducible and consistent performance. The system also had inherent damping in both directions and it was questionable whether the requirements for both rapid set-back and slow return could be satisfied.

Figure 6 (c) represents a magnetically damped spring mass system. This concept offered the potential of achieving a relatively constant net driving force of the set-back pin by algebraic addition of the force versus distance curves of the spring and the attractive magnets. Preliminary analysis indicated that the magnetic force was marginal and that the resulting force curve results in a nonlinear system for the equations of motions. A complete analysis of these equations of motion would require computer analysis, the funds for which were not available under this contract.

Figure 6 (d) illustrates a concept incorporating a ratchet/pawl escapement mechanism to retard the forward motion of the set-back pin. Although the full details of its operation were not available, it appeared that the escapement disengaged on the downstroke and rotated into engagement during the downstroke by a tang following a helical groove in the set-back pin. On the return stroke the escapement functioned to damp or retard that motion. This concept appeared unfeasible because of the difficulty in fabricating and assembling the several intricate components and reliability would appear to be adversely affected by the complexity. It was estimated that the teeth on the pawl and the ratchet would be in the range of 0.005 to 0.010 in. deep.

Figure 6 (e) shows a concept incorporating a porous plug, a bellows, a sliding seal, and a ballcheck valve. The bellows and sliding seal on the surface of the porous plug served to isolate the air in the cavity from the outside so that flow could enter only through the porous plug or the check valve. On the downstroke, damping was avoided by venting air out the bottom of the cavity through the check valve. On the return stroke, the check valve seated, causing the air to enter through the porous plug restrictor, thereby achieving damping. A

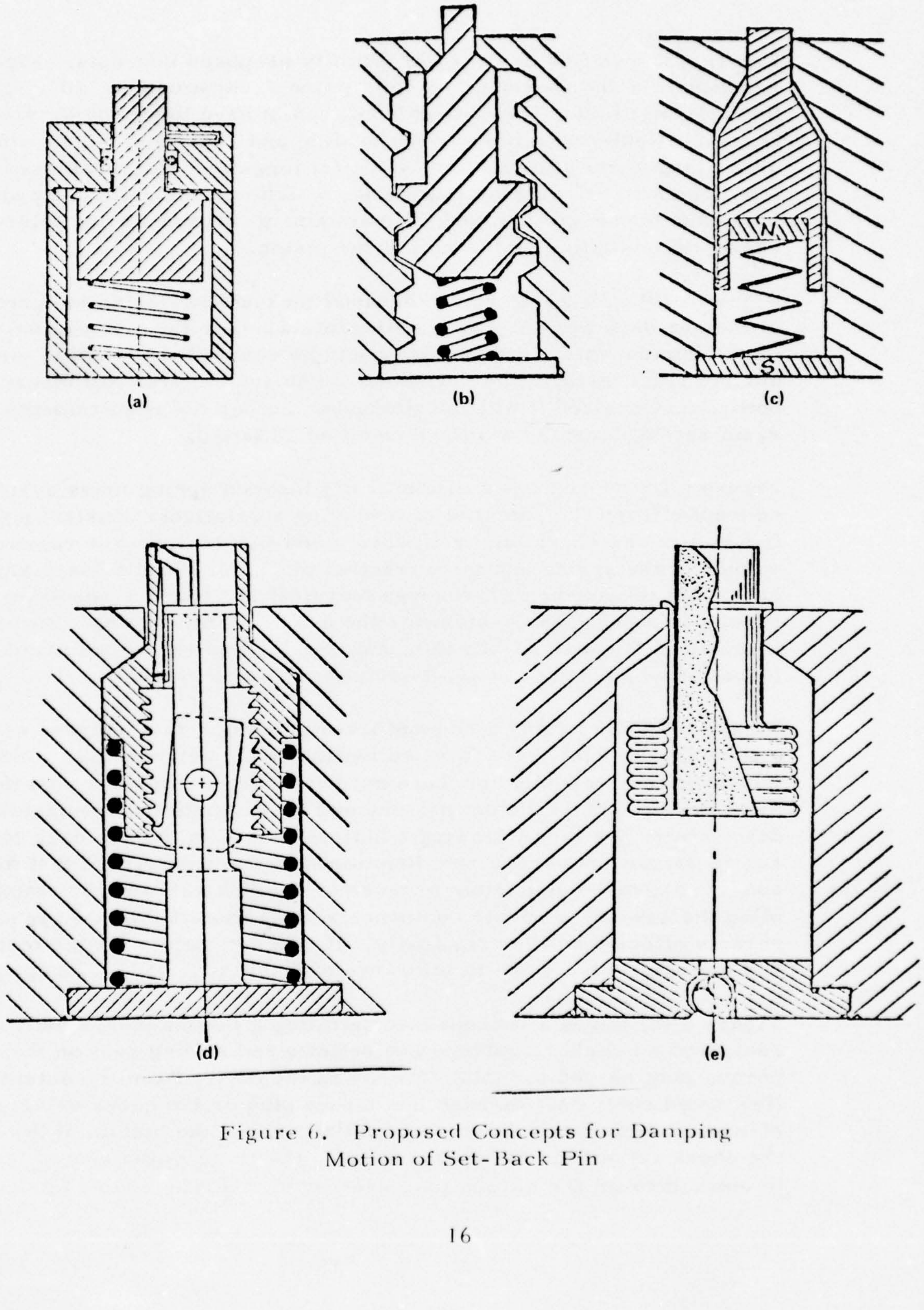

Figure 6. Proposed Concepts for Damping Motion of Set-Back Pin

A check valve arrangement in the base plate is unacceptable since tight clamping in the S&A assembly would prevent air breathing. The bellows concept was further studied by AOMC and is presented later in this section of the report.

Figure 7 shows the balance of the design concepts generated by others during the proposal effort which were also investigated. In Figure 7(a) is a design similar to a dashpot device. In this concept, the set-back pin acted as close fitting piston, which on the downstroke forced air from the bottom side out through a flow channel to the top side of the piston; and on the return stroke the reverse occurred. The primary drawback of this design appeared to be the difficulty in machining and controlling tolerances on the flow channel so that predictable performance would result. Also, damping would occur on both the downward and return stroke, a situation which would be irreconcilable with actual performance requirements.

Figure 7(b) shows a design which incorporated a lock-out feature. On the set-back stroke the tangs on the pedestal passed into the cavity in the set-back pin to lock the set-back pin in the retracted position. Since this concept incorporated lock-out features which were not acceptable under the Scope of Work requirements, no further analysis was made.

Figure 7(c) illustrates a locking ball concept. On the set-back stroke, movement of the set-back pin brought the balls in alignment with the circumferential groove cut in the lower plate. In this position, in the absence of spin, the balls would be oriented as shown in Figure 7(d), and return of the pin to its original position could occur. On application of spin, however, the balls would shift to the orientation shown in Figure 7(e) to provide locking until the spin dissipated.

This concept was attractive but appeared to be rather complex and difficult to assemble. Fabrication of the internal groove in the plate could also be difficult. It also appeared that the system could inadvertently lock-out in the absence of spin or possibly that locking could be difficult to maintain even under spin condition. In addition, this system is not truly damped and may be just as susceptable to relockup as the present M739 tilt pin. The configuration of the internal groove and the ramp angle were critical features and would have to be carefully controlled to assure satisfactory performance under all set-back and spin environments. Therefore, this concept was also eliminated from consideration.

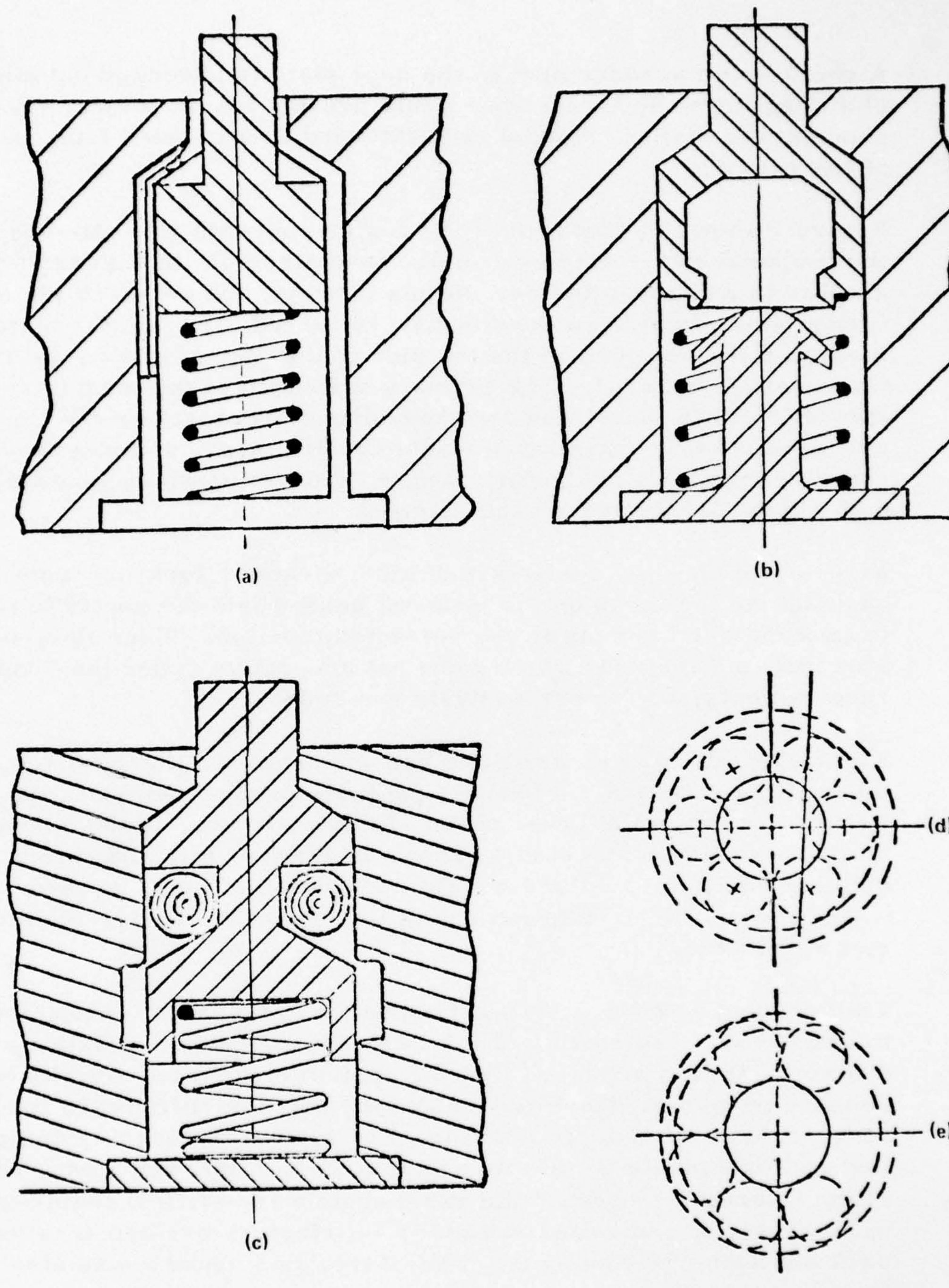

Figure 7. Concepts for Damping Motion of the Set-Back Pin.

5.1.2 AOMC's Concepts

5.1.2.1 Bellows Design

The bellows concept (Figure 8) for the set-back pin was investigated. The design uses the bellows for two functions (1) a bias spring, and (2) hermetic seal chamber for the sintered metal disc. The designs consists of a bellows, set-back pin, sintered metal plug, sleeve, check valve, check valve seat, and closure disc.

When the pin subassembly experiences a set-back force the bellows acting as a bias spring begins to compress. As the bellows compresses, it is moving or evacuating trapped air within the bellows through the check valve and passing the air through the orifice port holes out to the atmosphere. When the pin subassembly is fully compressed most of the air is now evacuated and at this moment the check valve, assisted by a light return spring, closes. As soon as the set-back force ceases, the pin subassembly attached to the bellows slowly returns in a damped motion. Delay time is governed by the air flow rate through the sintered metal disc. Flow rate is selected based on delay time required to allow the rotor assembly to arm and lock.

Due to the projected production cost of the bellows concept this design was terminated. Table 1 shows the cost comparison with the floating O-ring concept and existing system used in the M739 Fuze.

5.1.2.2 Long Tube Orifice Design

Two basic long-tube orifice designs were also investigated (1) orifice diameter less than 0.010-in. (i.e., hypodermic needle type) and (2) orifice diameter which could be fabricated by machining (i.e., diameter greater than 0.0135 in.).

The long-tube orifice design using hypodermic tube was investigated to determine what orifice diameter would be required to obtain a delay time greater than 100 msec. The analysis indicated that a delay time equal to or greater than 100 msec required a hole through the piston approximately 0.002 to 0.004 in. diameter, which is too small to be practical. Any small foreign particle would easily clog the orifice; thus, pneumatically locking the set-back pin. Therefore, the design was eliminated from consideration. The orifice design analysis is presented in Appendix E.

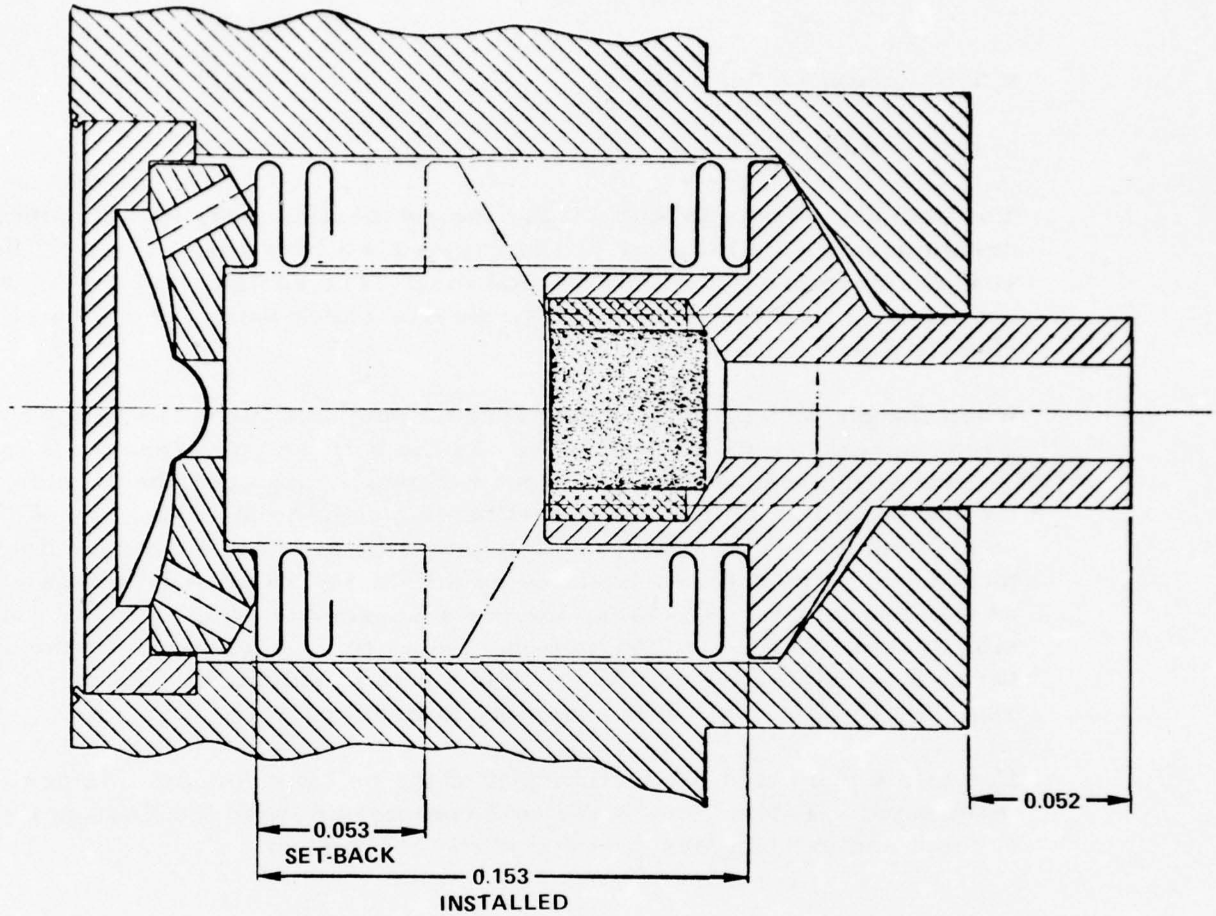

Figure 8. Bellows Concept.

Table 1. Cost Comparison of Bellows and Floating O-Ring Concepts with existing M739 Type S&A Device.

Concept	Tooling	Production Cost/Rate		
		100K/Month	200K/Month	300K/Month
Floating O-Ring	$80,000	0.368	0.362	0.362
Bellows	$60,000	3.864	3.829	3.829
M739 Type	--	0.12	0.12	0.12

The removal of the porous disc was suggested by Picatinny Arsenal to determine whether the damped set-back pin could be dampened by the combination O-ring friction and air throttling through a machined orifice. By exercising the CSMP computer program (i.e., math modeling), Figures 9 and 10 were generated. The curves illustrate how the damped set-back pin assembly responds without the porous plug and using only the machined bleed hole through the center of the pin. Two orifice sizes (0.030 and 0.0135 in. diameters) were investigated. The test case used was the 155mm gun at Zone 1 condition.

The above computer test cases indicated that a maximum of 37-msec delay time could be expected using a 0.0135-in.-diameter orifice. The delay time was considered inadequate for use in the damped set-back pin system, so the design was eliminated from consideration.

5.1.2.3 High O-Ring Friction Design

Tests were conducted to investigate O-ring squeeze versus friction force to increase the bias spring force to increase the ΔV characteristics of the damped set-back pin system. The data shown in Table 2 indicated that a friction load greater than 70 gm could not be attained prior to O-ring buckling. The force which the concept required was 77 gm, which was the maximum friction force allowable in the damped set-back pin system due to the lowest available acceleration force (i.e., 155mm, Zone 1). It was also concluded that the O-ring friction of 77 gm could not maintained throughout the range of tolerances of mating hardware and temperature extremes. As noted in Table 2, a diametrical squeeze of 0.015 in. had a breakout force of 38 gm and a diametrical squeeze of 0.018 in. had a breakout force of 70 gm. When the O-ring was exposed to cold temperature, friction increased another 37%. This concept was discarded due to the large varication of O-ring friction forces which would cause an erratic delay time.

5.1.2.4 Celgard Plastic Restrictor

Late in this study program samples of porous plastic material were investigated as a possible flow restrictor to obtain delay time. Several damped set-back pins were assembled as shown in Figure 11. Test conducted at ambient conditions indicated that delay could be obtained using this design concept. A comparsion of the Celgard plastic restrictor with the sintered meter restrictor is shown in Table 3.

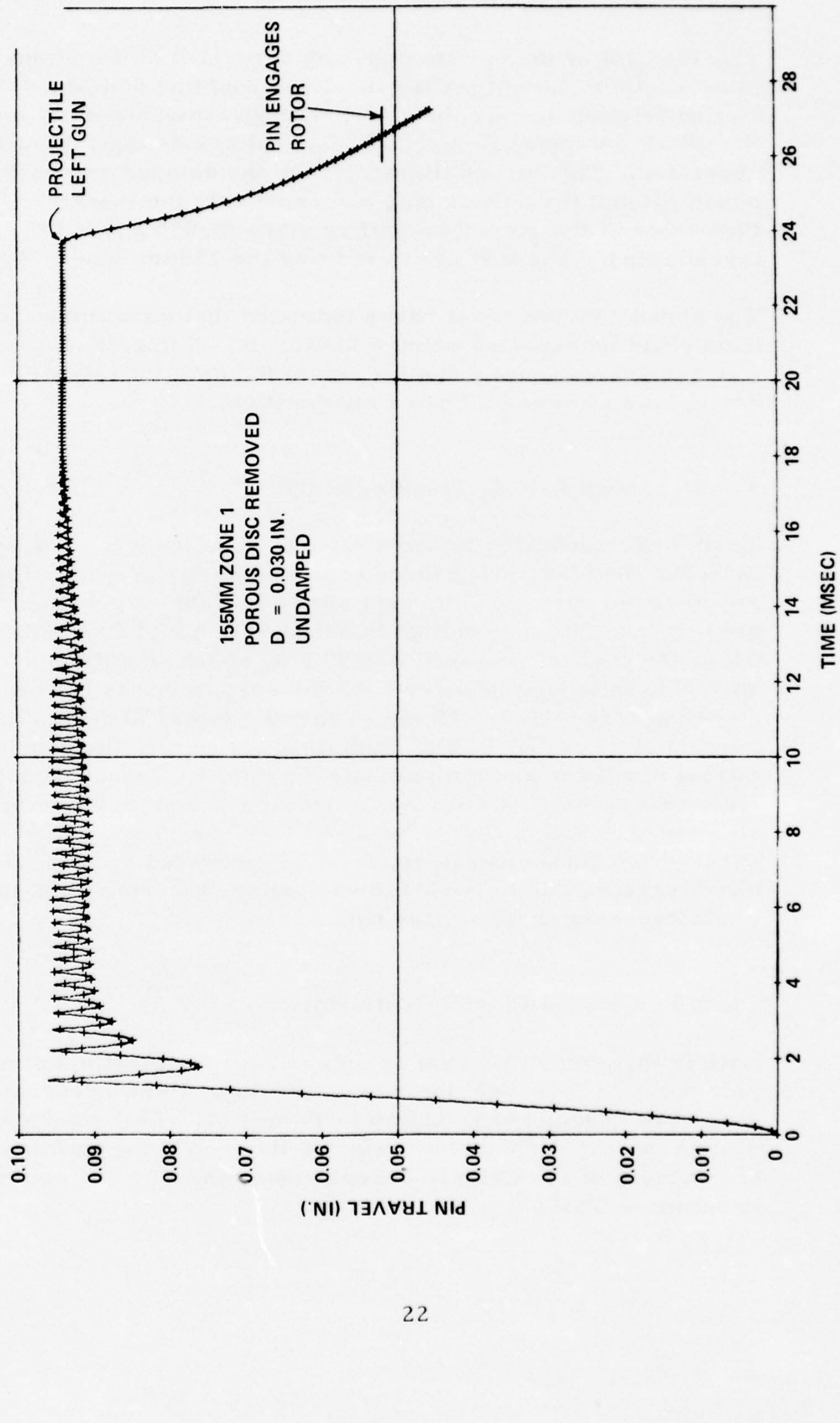

Figure 9. Dynamic Response with 0.030-in. Bleed Hole.

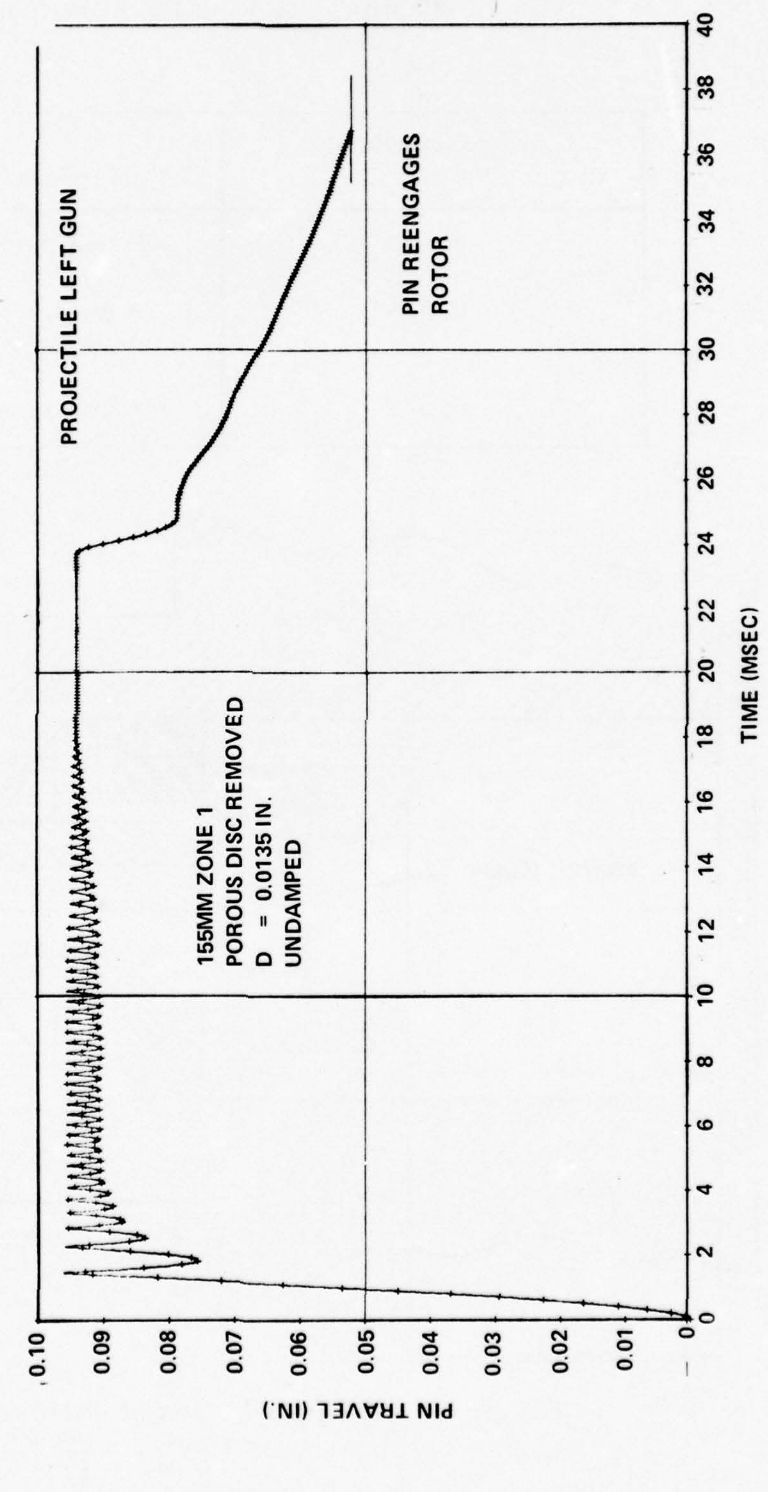

Figure 10. Dynamic Response With 0.0135-in. Bleed Hole.

Table 2. O-Ring Buckling Test.

Diametrical Squeeze (in.)	Forces/Remarks
0.020	O-ring buckles
0.018	70 gm breakout - slight buckling was observed.
0.015	38 gm breakout

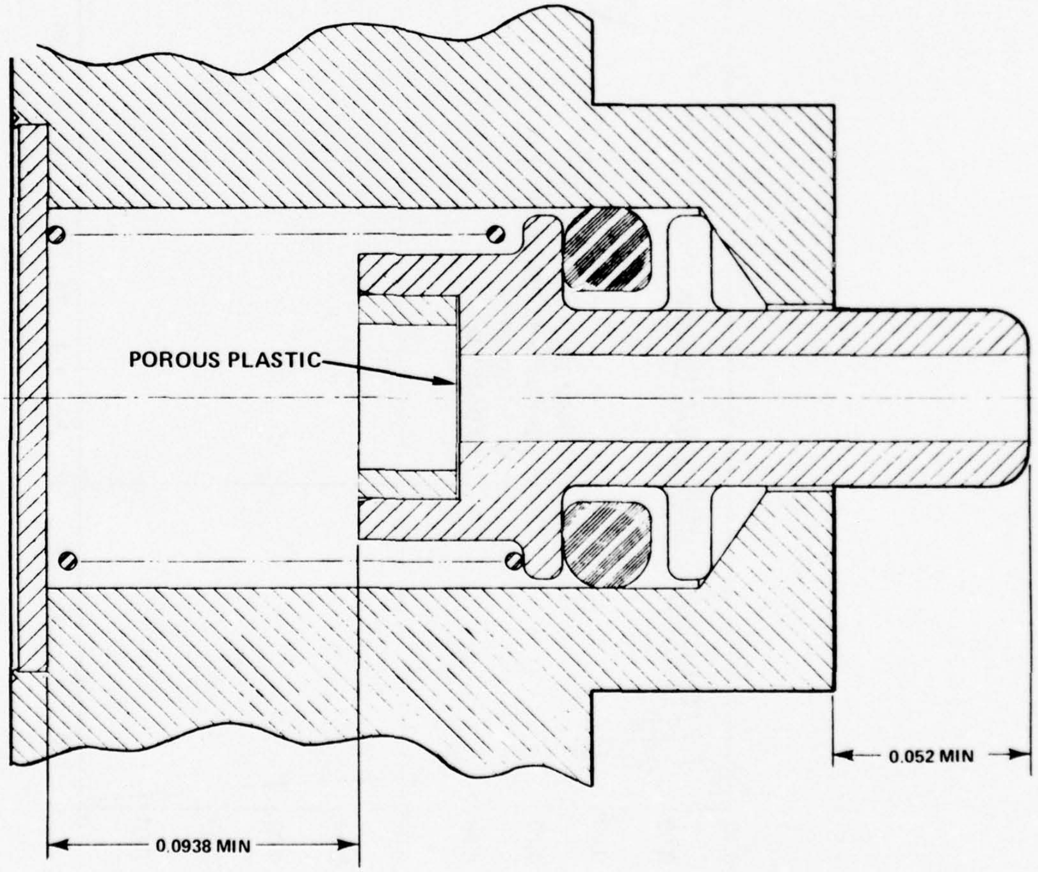

Figure 11. Celgard Plastic Restrictor Concept.

Table 3. Restrictor Material Comparison.

Property	Metallic Sintered Stainless, Type 316	Plastic Polypropylene Film (Celgard)
Effective pore size (microns μ)	0.5	0.02 - 0.04
Flow rate (cc/cm^2-min)	20	33
Thickness (mils)	50	1
Pressure drop (N_2)	7	7
Ultimate tensile strength (psi)	120,000	2000
Temperature usage (°F)	Relatively unlimited	-80 to 160
Elongation (%)	0 - 12	50

The Celgard film was a product of Celanese Laboratories. The plastic film had the following characteristics:

- It was a polypropylene film with excellent resistance to acids, bases, and most chemicals.
- Film had controlled uniform microporosity and structural uniformity.
- It was highly permeable to gases and water vapor, yet was "waterproof".
- Film was available in both hydrophobic and hydrophilic grades.
- Could be fabricated to itself or other materials for a variety of applications.

Preliminary tests indicated that this material could replace the porous sintered metal disc.

5.1.2.5 Teflon O-Ring

Teflon material for the O-ring was investigated. The O-ring manufacturer, however, recommended that a Teflon O-ring should not be used in the damped, set-back pin system because (1) the Teflon has plastic properties and lacks the memory characteristics of rubber, thus causing a leak path between O-ring and wall (Teflon will take a compression set more easily than rubber); and (2) a Teflon O-ring is harder than a rubber O-ring, thus causing a wide range of squeeze variation due to assembly tolerances (i.e., wide range of squeeze means a wide range of frictional force). Therefore, Teflon was dropped from consideration.

5.1.2.6 High Return Spring Force (500g)

Higher g-load springs were investigated but two problems exist if the return spring force is too high

a. High spring force acting on the damped set-back pin causes greater travel in the undamaged condition (initial jump-up).

b. An early return of the pin will cause the rotor to be locked by the side loading by the pin assembly.

Therefore, the high-g springs were dropped from investigation.

5.2 MATHEMATICAL MODEL

A porous device was investigated as a gas glow restrictor to produce time delays by reducing flow rate. A porous device contains many small, torturous flow paths, many of which interconnect. The flow paths are of irregular and varying cross-section, so that an analytical solution to the flow problem was not possible during this study program. However, some analytical basis was required for the porous plug design, and this basis was arrived at by treating an equivalent length of simple tubing analytically, so that the effects of the various parameters were approximated. The equations of motion of the set-back pin derived during this program are as follows:

a. During Run-Up

$$\ddot{X} = \frac{F_o}{m} - \frac{k}{m} X + (P_{out} - P_{in}) \frac{A^*}{m} - \ddot{z} \pm \frac{f_o}{m} \tag{1}$$

if $\dot{X}$ is positive

$$P_{out} = \frac{N_o RT + \frac{\pi D^4}{256\mu\ell} P_{in}^{\,2}(\tau) - \frac{\pi D^4}{256\mu\ell} \int^{\tau} P_{out}^{\,2}\, d\tau}{V_o^* + A^* X} \tag{2}$$

if $\dot{X}$ is negative

$$P_{out} = P_{in} \tag{3}$$

b. In the tube, rifling engaged

$$\ddot{X} = \frac{F_o}{m} - \frac{k}{m} X + (P_{out} - P_{in}) \frac{A^*}{m} - \ddot{z} \pm \left[\frac{f_o}{m} + \phi r \left(\frac{2\pi}{20C}\right)^2 \dot{z}^2 + \phi r \left(\frac{2\pi}{20C}\right)^2 \ddot{z} \right] \tag{4}$$

plus Equation 2 or 3, as appropriate.

c. After leaving the tube

$$\ddot{X} = \frac{F_o}{m} - \frac{k}{m} X + (P_{out} - P_{in}) \frac{A^*}{m} - \ddot{z} \pm \left[\frac{f_o}{m} + \phi r \left(\frac{2\pi}{20C} \right)^2 \dot{z}^2 \right] \quad (5)$$

plus Equation 2 or 3, as appropriate.

5.2.1 Computer Simulation

To investigate system behavior, two computer programs (Appendix F) were developed using the math model. The first of these utilizes a Continuous System Modeling Program (CSMP) that simulates the operation of an analog computer on a digital computer. This program employs a block-oriented language to solve the differential equations describing the complete motion of the set-back pin as they would be solved on an analog computer. This is an exact simulation of operation, valid for any input condition such as varied weapons, charges, friction factors, flow rates, pin weights, etc. Figures 12 and 13 illustrate the dynamic response of the pin at Zone 1 conditions of a 155mm howitzer and Figures 14 and 15 illustrate the response at Zone 8 conditions of a 155mm howitzer. Figures 12 and 14 show undamped and critically damped pin response to illustrate the minimum and maximum damping characteristics. Figures 13 and 15 illustrate the pin response if a coefficient of restitution of approximately 0.40 is assumed.

A comparison of the 8-in. howitzer with the 155mm howitzer showed that very little difference existed in response time. The 8-in. howitzer was only slightly faster in response time than the 155mm in both Zone 1 and Zone 8 firing conditions.

In all cases tested the pin did not rebound enough to reengage into the rotor assembly during actual firing conditions. The minimum pin actuation time was approximately 0.8 msec at Zone 8 and the maximum time was 1.5 msec at Zone 1.

The second program, written in Fortran IV, is a one-dimensional solution of the flow rate equation. It is valid only for the return stroke of the set-back pin. It runs much faster than the complete CSMP simulation and was therefore useful for only the return stroke of the pin to obtain final delay time for various parameters.

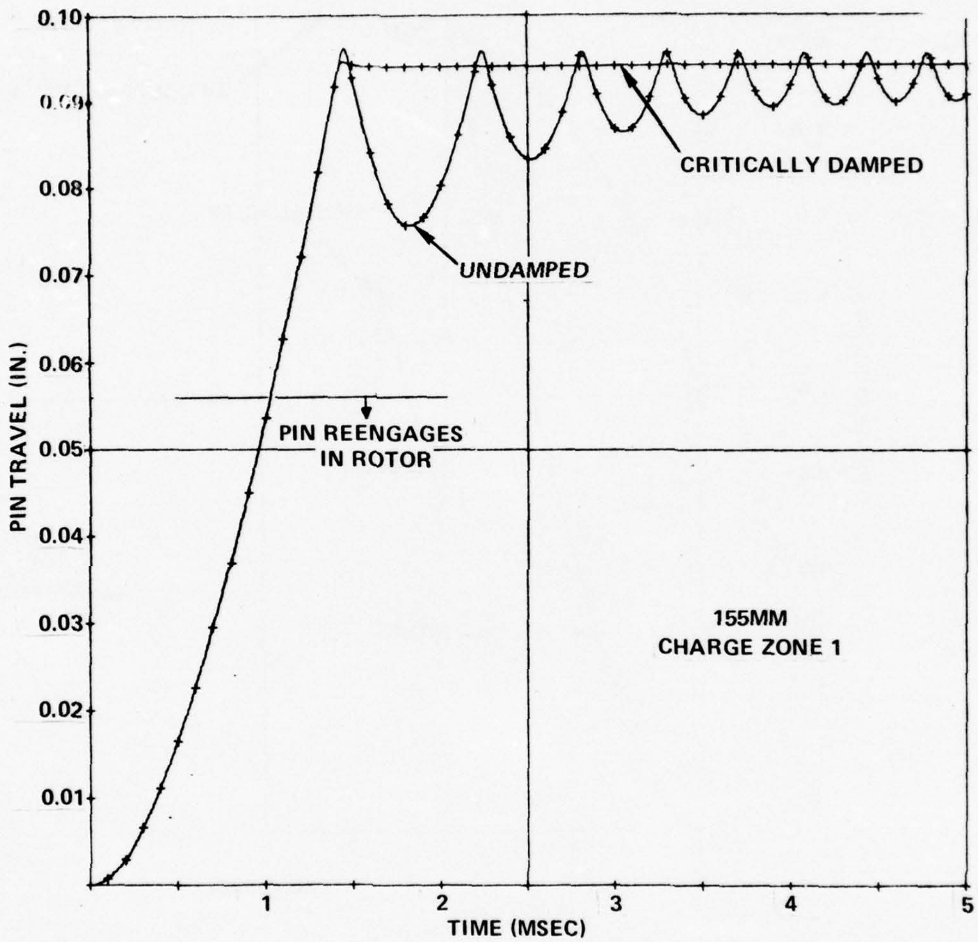

Figure 12. Critically Damped and Undamped 155mm Howitzer Charge Zone 1 Dynamic Response.

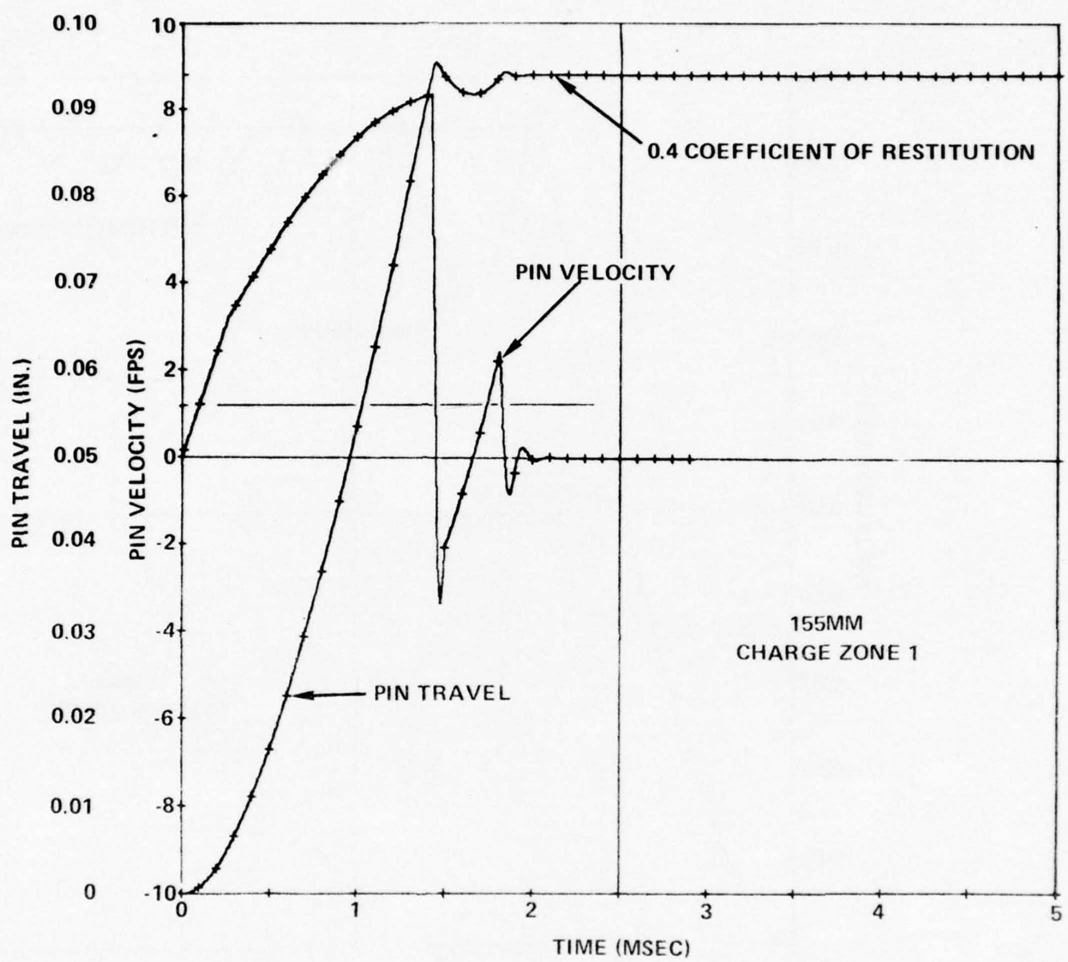

Figure 13. 155mm Howitzer Charge Zone 1 Dynamic Response with 0.4 Coefficient of Restitution.

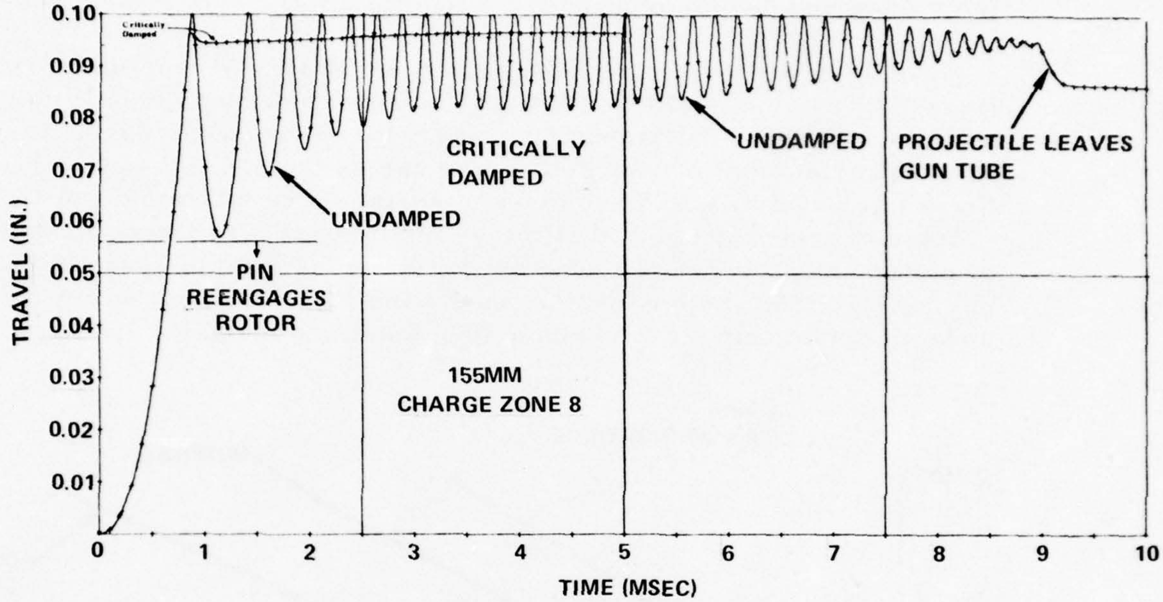

Figure 14. Critically Damped and Undamped 155mm Howitzer Charge Zone 8 Dynamic Response.

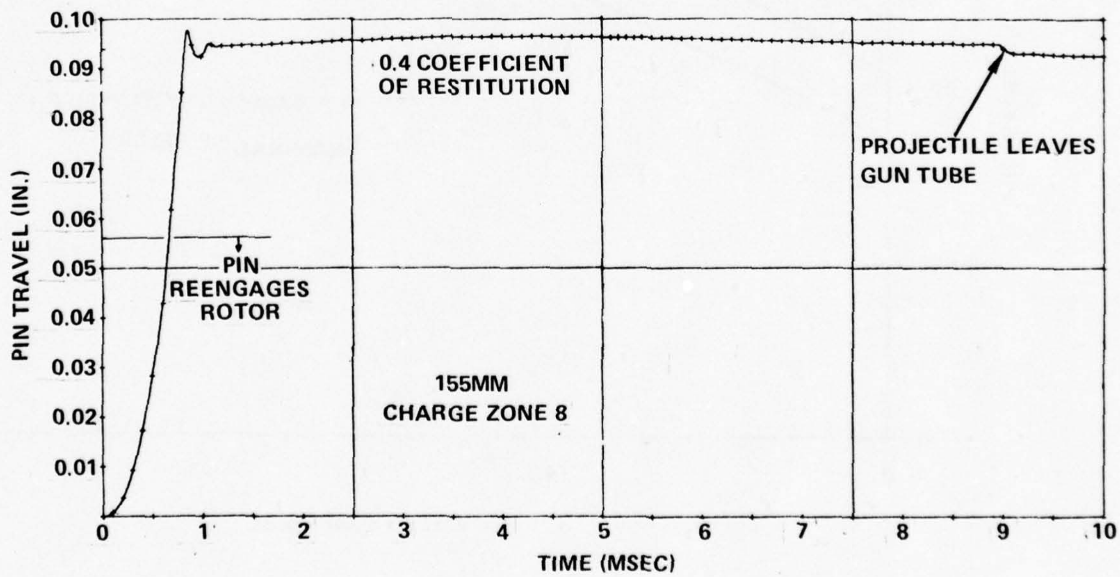

Figure 15. 155mm Howitzer Charge Zone 8 Dynamic Response with 0.4 Coefficient of Restitution.

This Fortran IV program was used in determining the proper tolerancing for the damped set-back pin assembly by performing a parametric study on the spring and porous plug.

Figure 16 shows the spring tolerance sensitivity. At nominal spring force (0.100 lb) and nominal flow rate (0.036185 cc/sec) the delay time measured by the computer simulation is 0.8 sec. By changing the spring force and rate by ± 10% from nominal the delay time varies from 0.575 sec at + 10% spring force tolerance to 1.125 sec at -10% spring force tolerance. Also noted on the graphic representation is that the Y-axis intercept of the curve is near 0.020in. of pin travel. This is the undamped jump-up of the pin assembly prior to damping action. Experimental results indicated approximately 0.018 in. undamped jump-up travel when a 300g (nominal 0.100 lb) spring is used.

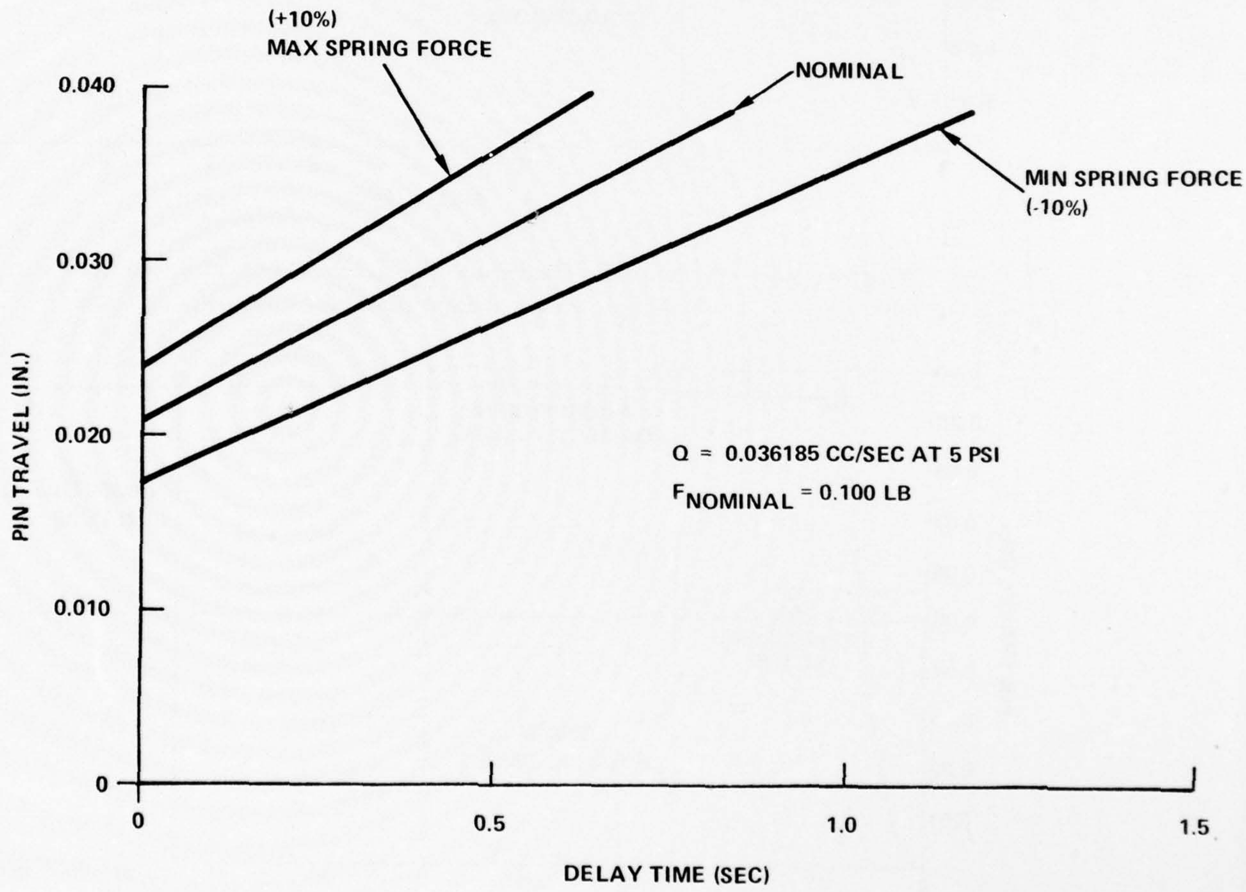

Figure 16. Bias Spring Sensitivity.

Figure 17 shows the porous disc tolerance sensitivity. At the nominal flow rate the delay time is approximately 0.775 sec; this line is not shown on the graph but it can be interpolated as being between +5% and -5% lines. As the porous disc flow rate is increased by 30% above nominal, the delay time approaches 0.6 sec when the spring force is held constant. And as the flow rate is decreased by 30% below nominal, the delay time is nearing 1.10 sec.

Combining the two variance of the porous disc and spring tolerances to obtain the worst possible conditions of maximum and minimum delay times results in a tolerance spread as shown in Figure 18. A ±5% on the spring combined with a ±10% on the flow rate results in a delay time spread from 0.60 to 1.012 sec. These delay times would satisfy selected safety aspects of the S&A device but it is difficult to say how easily the tolerances of the hardware can be met by the manufacturer of components parts. For instance, the normal spring tolerance by spring manufacturers is ±10% on required spring loads. It is difficult to determine what tolerance can be maintained by the manufacturers of sintered metal disc with respect to flow rates. One company has been maintaining less than 3% tolerance (0.1987±0.0045 lb/cu in.^{3}) on density but the correlation of density to delay time could not be established due to randomness of data point. (See Section 5.5 on test data.)

5.3 TOLERANCE STUDY

A tolerance study was conducted on the damped set-back pin assembly to determine maximum and minimum pin travel before coming in contact with the rotor assembly. Figure 19 is a summary of the study.

The study showed that a minimum of 0.043 in. and a maximum of 0.078 in. pin travel could exist when the damped set-back pin is assemblied to the S&A device. To determine delay times the minimum pin travel of 0.043 in. was used.

5.4 RELIABILITY AND SAFETY ANALYSIS

5.4.1 Reliability

The damped set-back pin assembly is designed to meet the safety requirement necessary for protection of personnel and equipment that handle the kill mechanism. However, the failure of the damped set-back pin that could affect safety does not directly constitute a critical failure mode in which personnel or equipment may be in jeopardy because two sequence modes of arming environments are necessary -- set-back force and spin.

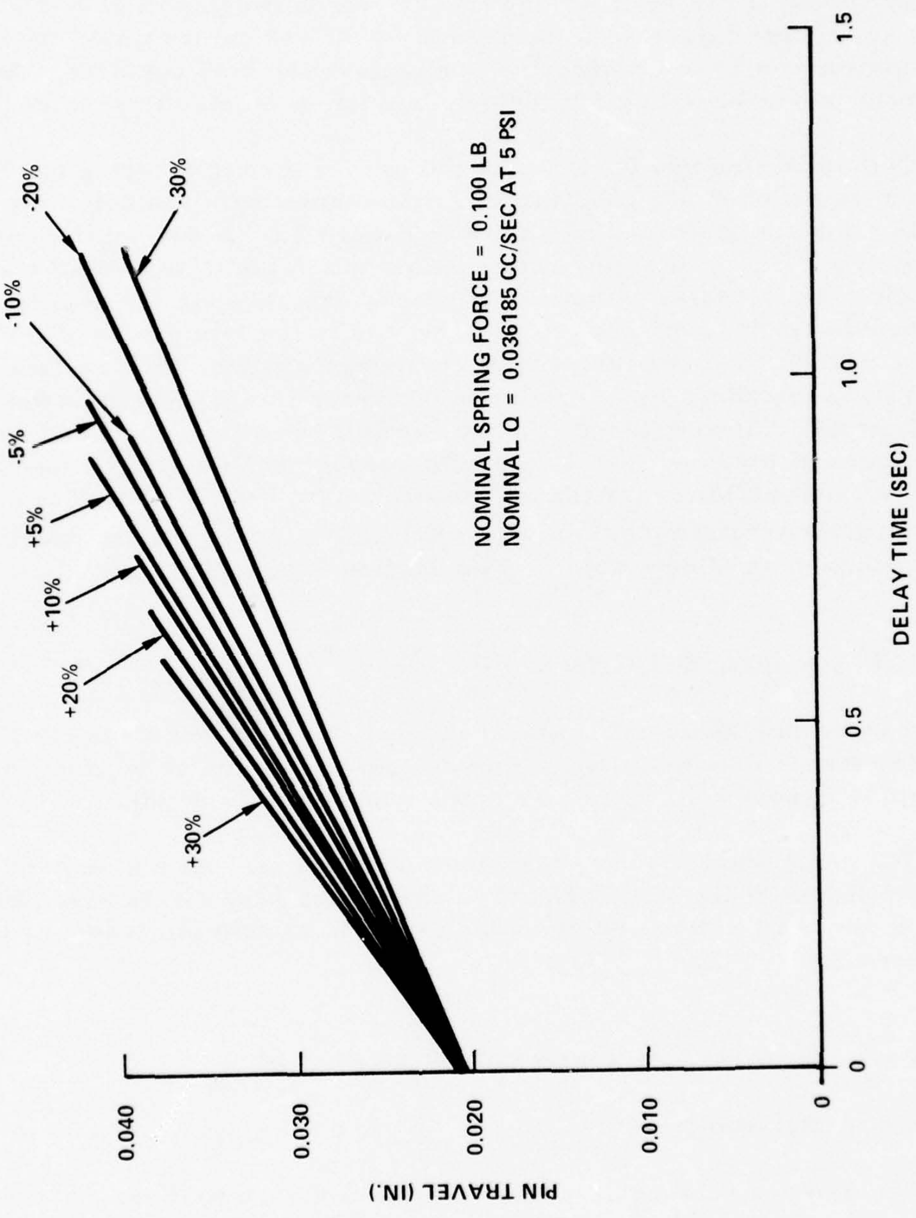

Figure 17. Porous Disc Sensitivity.

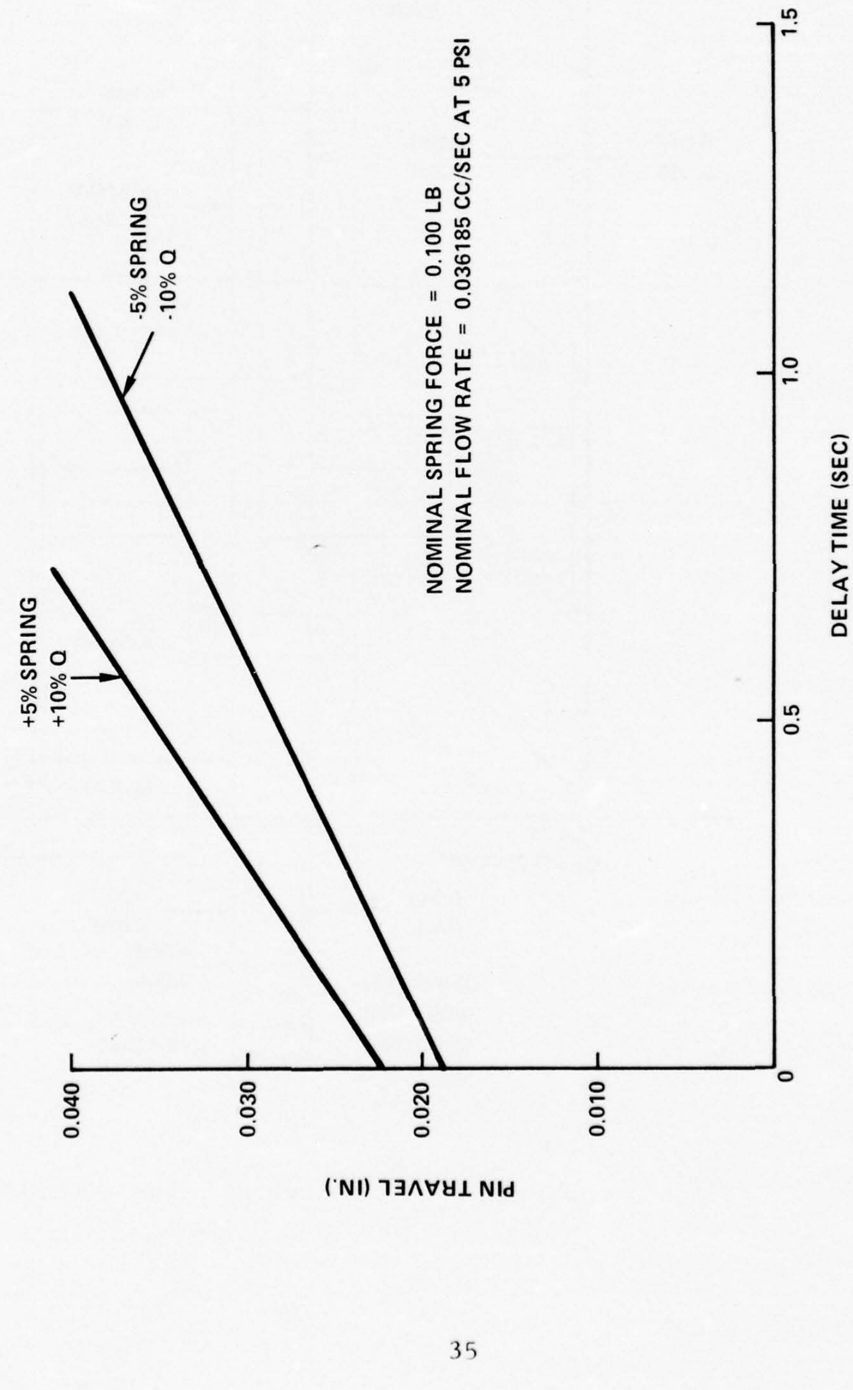

Figure 18. Combined Sensitivity.

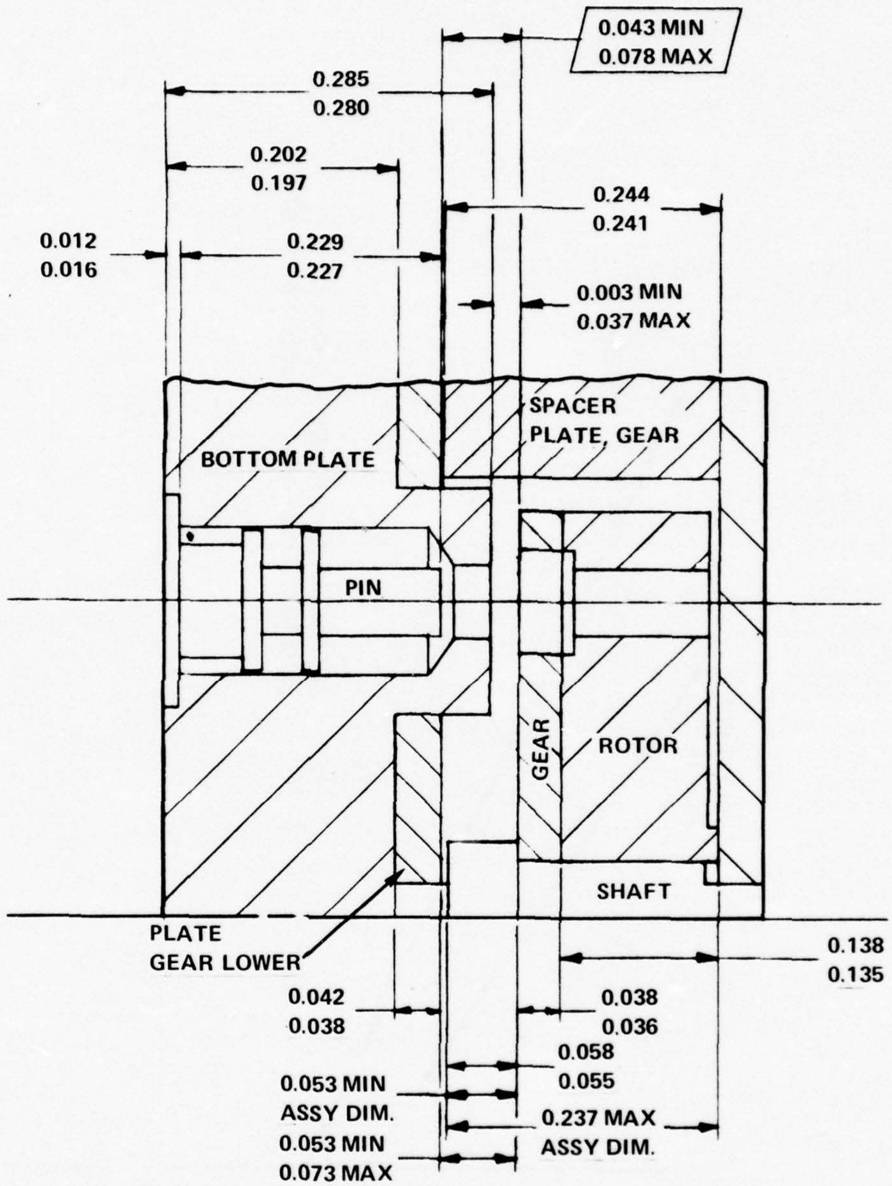

Figure 19. Set-Back Pin Travel Before Engaging Rotor.

The safety failure modes and effects analysis (FMEA) analyzed that portion which directly affects the damped set-back pin assembly and did not include the rotor section blocks of the flow diagram (Figure 20). The FMEA illustrates what may cause an unsafe situation in the damped set-back pin assembly. Preventive action for these possible unsafe conditions was shown to be basically an inspection procedure rather than a design idscrepancy.

5.4.1.1 Failure Mode and Effects Analysis

The FMEA (Table 4) was conducted to identify potential system weaknesses. This analysis utilized the functional flow block diagram and the reliability mathematical model.

The analysis was divided into functional groups (Figure 20); it began at the arming environment level and expanded to the component or part level. The possible modes of item failure and the possible effects of these failures on the functional requirements of the S&A were defined. Each item included a description of its success and failure criteria, as well as potential and well-known failure modes. In addition, each item was categorized by probability of occurrence and by criticality of the effect on end-item performance. Recommenddations for reducing the frequency of occurrence within each failure mode were also included in the analysis.

5.4.1.2 Reliability Assessment

A reliability math model was developed from the functional flow block diagram (Figure 20). This math model used standard series/parallel probability equations to relate the system reliability to the part reliability.

Reliability apportionment (Table 5) was performed to determine the final reliability value of the damped set-back pin assembly. The order of difficulty was based on the compression of the spring., and a value of .9999 was selected. All values were based on best engineering judgement.

The model was represented by the general equation:

$$R_s = \prod_{i=1}^{n} R_i$$

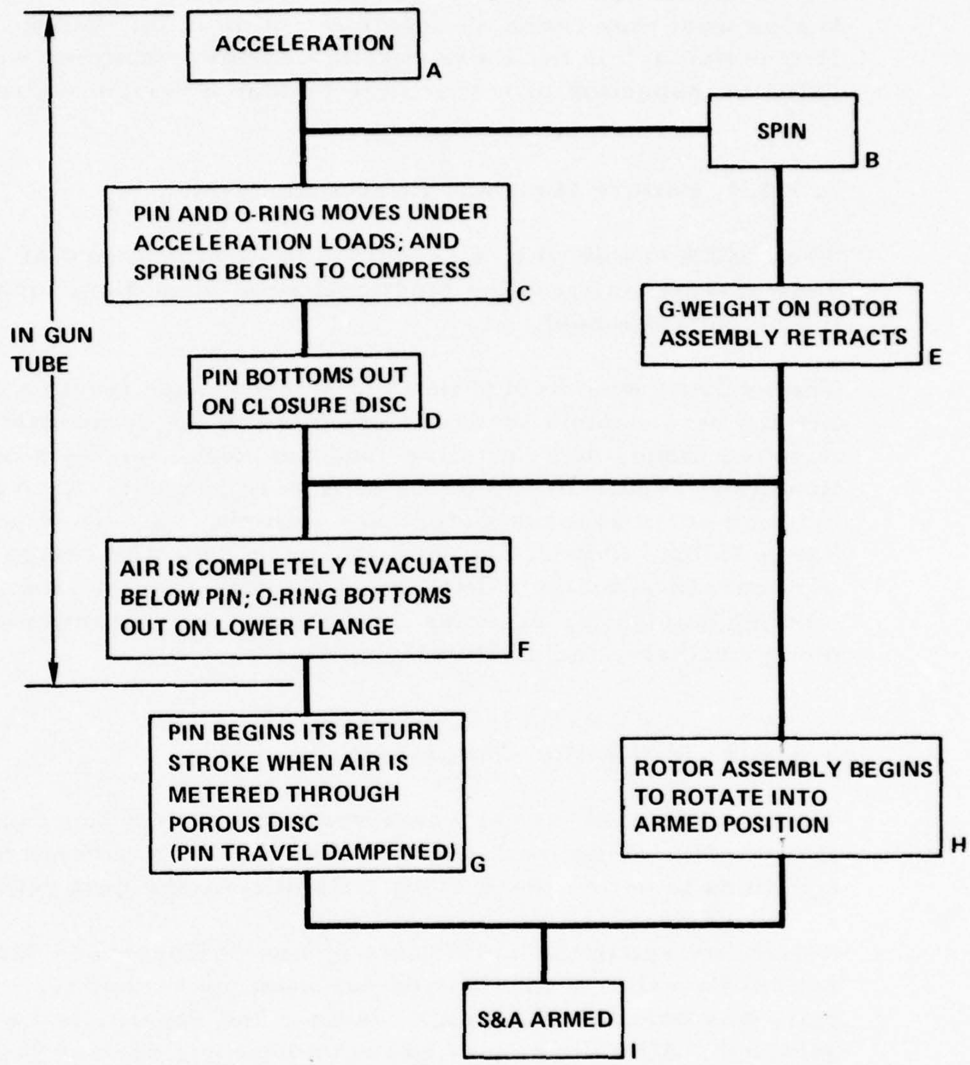

Figure 20. Functional Flow Block Diagram.

Table 4. Failure Mode and Effects Analysis.

* COMPONENT IDENTI-FICATION	COMPONENT PRIMARY FAILURE MODE	CAUSE(S) OF FAILURE	EFFECT OF FAILURE ON FUNCTION	PROBABILITY OF FAILURE MODE OCCURRENCE	FAILURE CLASSIFICATION	CORRECTIVE ACTION
C Damped Set-Back Subassy	1. Pin does not move back under acceleration load. 2. Missing pin assembly.	1. Foreign object causes pin to jam. 2. Missed assy operation.	1. S&A fails to arm. 2. S&A lacks one of two safety features.	Low Low	Major Critical	1a. Assembly in clean room. 1b. Inspect for foreign matter. 2. Inspect for pin assy.
C O-ring	1. Broken O-ring. 2. O-ring has surface defects. 3. Missing O-ring.	1a. Material defect. 1b. O-ring stretched excessively. 2. Manufacture's fabrication technique inadequate. 3. Missed assy operation.	1-3. No delay on pin-fails to arm.	Low	Major	1. Inspect O-ring before and after assy. 2. Contact O-ring manufacturer to upgrade quality control. 3. Inspect for missing O-ring.
C Return Spring	1. Broken or bent spring. 2. Missing spring. 3. Spring force too high. 4. Spring force too low.	1. Rough handling of spring. 2. Missed assy operation. 3-4. Spring out of tolerance.	1,2. S&A lacks one of two safety features. 3. (Spring force too high) - Short delay time causing dud. 4. (Spring force too low) - Pin does not return if projectile is accidently dropped.	Low Low Low	Critical Major Critical	1,2. Instruct assemblers to handle springs with care. 3,4. Inspect spring for conformance of design.
D Closure Disc	1. Closure disc falls off. 2. Closure disc leaks air.	1. Inadequate crimping. 2. Lacks sealing compound,	1,2. No delay. S&A dud.	Low	Major	1,2. Inspect crimp and sealing.
F Damped Set-Back Subassy	1. Pin does not move back under acceleration loads.	1a. Missing vents on upper flange.	1. S&A dud.	Low	Major	1a. Inspect for pin features.

* Letters in parenthesis indicated functional flow "block".

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Table 4. Failure Mode and Effects Analysis. (Continued)

COMPONENT IDENTI-FICATION	COMPONENT PRIMARY FAILURE MODE	CAUSE(S) OF FAILURE	EFFECT OF FAILURE ON FUNCTION	PROBABILITY OF FAILURE MODE OCCURRENCE	FAILURE CLASSIFICATION	CORRECTIVE ACTION
F O-Ring	1. O-ring does not seal on lower flange surface.	1. Inadequate seal between O-ring and flange.	1. Reduce delay time.	Low	Major	1. Grease O-ring to insure seal.
G	1. No delay. 2. Excessive delay.	1a. Leakage around sleeve and sintered metal disc. 1b. Missing sintered metal disc.	1. No arming of S&A - dud.	Low	Major	1. Inspect assy force of installing sleeve into pin.
		2a. Sintered metal contaminated with foreign material. 2b. Burrs on pin. 2c. Pin jams in retracted position.	2. One of two safety features inactive.	Low	Critical	2a. Assemble in clean area. 2b, c. Inspect for contamination and burrs on pin.

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Table 5. Reliability Apportionment.

Block	Description	Rationale for Apportionment Value	Order of Difficulty	Reliability
A	Acceleration	Gun fires at required level.	0	1
B	Spin	Projectile spins under "A" condition.	0	1
C	1. Pin moves under acceleration loads.	1. Must compress spring. 2. Must overcome O-ring friction.		
	2. O-ring moves under acceleration loads.	Must overcome O-ring friction		
	3. Spring begins compress	Used this item to base all reliability numbers. (.9999)	6	.9994
D	Pin bottoms out on closure disc	See Block C	6	.9994
E	G-weight on rotor assembly retracts	This item is assumed to function 100% (not part of this study program.)	0	1
F	1. Air is evacuated	1. See Block D 2. Air must pass O-ring and flange.		
	2. O-ring bottoms out on lower flange	See Block D	13	.9987
G	1. Pin begins its return stroke.	1. Spring must act on pin. 2. O-ring must be moved. 3. Air must be metered through porous disc.		
	2. Air is metered through porous disc	1. Porous disc must be clean from grease and other matter. 2. Manufactured with correct density 3. Air is passed through disc rather than around disc.		
	3. Pin travel damped	See Block G	18	.9982
I	S&A armed	- - - - -	-	.9957

where

R_s = system reliability

$R_i = R_j + R_{j+1} - R_j R_{j+1}$

and

R_j = a subsystem composed of two independent subsystems in parallel.

Using the function flow block diagram the reliability math model of the damped set-back pin became

$$R_s = C\ D\ F\ G\ I\ J\ K\ L\ M$$

Using the reliability apportionment (Table 5) the reliability of the S&A device was determined to be .9957 when a reliability of 1.0 was assumed for the spin, acceleration, and rotor assembly. These items were assumed to be 1.0 because it was assumed acceleration and spin are attained and that it was not the responsibility of this program to investigate the rotor assembly portion of the S&A device. Thus, the reliability value of .9957 is related to the damped set-back pin assembly only. If the reliability value of the rotor assembly was known, this value multiplied by .9957 would result in a total S&A device reliability number in the environment of minimum acceleration and spin.

5.4.2 Safety Analysis

5.4.2.1 Safety Failure Mode Analysis

The damped set-back pin design was evaluated at the component/subassembly level to identify all conceivable modes of failure and their effect on end-item operation. This analysis (Table 6) identified failures critical to the operational success where system and personnel safety were affected. Each failure mode was evaluated in the potentially failed condition, and the failure was ranked according to the failure effect, severity, and probability of occurrence. This analysis was performed in conjunction with the reliability failure mode and effects analysis.

Table 6. Failure Mode and Effects Analysis.

DESCRIPTION OF FUNCTION	COMPONENTS INVOLVED IN EXECUTION OF FUNCTION	
Damped Set-Back Pin Assembly retracts and remains in retracted position prior to launch.	O-Ring Return Spring Damped Set-Back Pin Sintered Metal Disc (Porous Disc)	PAGE ____ OF ____ DATE ________ REVISION N/C

COMPONENT IDENTI-FICATION	COMPONENT PRIMARY FAILURE MODE	CAUSE(S) OF FAILURE	EFFECT OF FAILURE ON FUNCTION	PROBABILITY OF FAILURE MODE OCCURRENCE	FAILURE CLASSIFICATION	PREVENTATIVE ACTION
O-Ring	O-ring prevents forward movement of pin.	1. O-ring oversized. 2. Lacks lubrication.	Equipment and personnel safety hazard if installed in projectile.	Low	Critical	1. Inspect O-ring. 2. Inspect to ensure adherence to assembly procedure.
Return Spring	Insufficient spring force	1. Damaged spring. 2. Missing spring. 3. Weak spring.	Equipment and personnel safety hazard if installed in projectile	Low	Critical	1, 2. Inspect to ensure adherence to assembly procedure. 3. Inspect to ensure adherence to assembly procedure and design conformance.
Damped Set-Back Pin	Pin retracted (Jammed)	1. Burrs on pin. 2. Burrs on bottom plate. 3. Ramp angle incorrect in bottom plate	Equipment and personnel safety hazard if installed in projectile	Low	Critical	1-3. Inspect to ensure adherence to assembly procedure and design conformance.
Sintered Metal Disc	Contamination of disc.	1. Foreign matter. 2. Dust	Equipment and personnel safety hazard if installed in projectile.	Low	Critical	1-2. Inspect to ensure adherence to assembly procedure.

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A fault tree for analyzing the S&A device (Figure 21) was constructed to illustrate how undesirable events are caused. The undesirable events chosen were failures that could lead to death of personnel or severe damage of equipment when the secondary safety feature was defeated or functioned.

5.4.2.2 Safety Considerations

During this study program various safety considerations were analyzed with respect to handling safety. Safety considerations investigated included minimum velocity change, ramp-roll situation, delay time consideration, and G-T product discriminator.

5.4.2.2.1 Minimum Velocity Change

The spring-mass system of the damped set-back pin is required to be actuated under an acceleration of not less than 35g, although the preferred range is 500g. Picatinny Arsenal also suggested that a minimum change in velocity required to actuate the system be 200 fps. With this velocity change, an unintentional drop of the projectile from a height of approximately 621 ft would be necessary to actuate the spring-mass system. However, the design of the damped set-back pin system is such that only a 12.3 fps (theoretical) change in velocity (0.6-ft drop height) could be obtained. An attempt was made to increase this change in velocity by increasing the spring force; however, when a 500g spring was installed in the assembly, a 0.054-in. undamped travel resulted. When a 300g spring was used, the undamped travel of the pin was approximately 0.018 in. Therefore, the maximum spring load of 300g was selected for the damped set-back pin assembly which gave acceptable jump-up of the pin. The complete analysis of the 200 fps safety requirement is included in Appendix G.

5.4.2.2.2 Ramp-Roll

Although the damped set-back pin is retracted, under a base-down drop of 0.6 ft the projectile is considered safe as long as the projectile does not spin above 1100 rpm. Above this spin rate the rotor assembly could be activated. If the projectile was to be dropped on an inclined plane of approximately 67° from the horizontal, the projectile would acquire a 1100 rpm spin rate in 1.0 sec. Therefore, this must be the maximum delay time of the damped set-back pin assembly. The time of 1.0 sec to acquire a 1100 rpm spin rate is conservative because the analysis (see Appendix H) neglected rolling friction

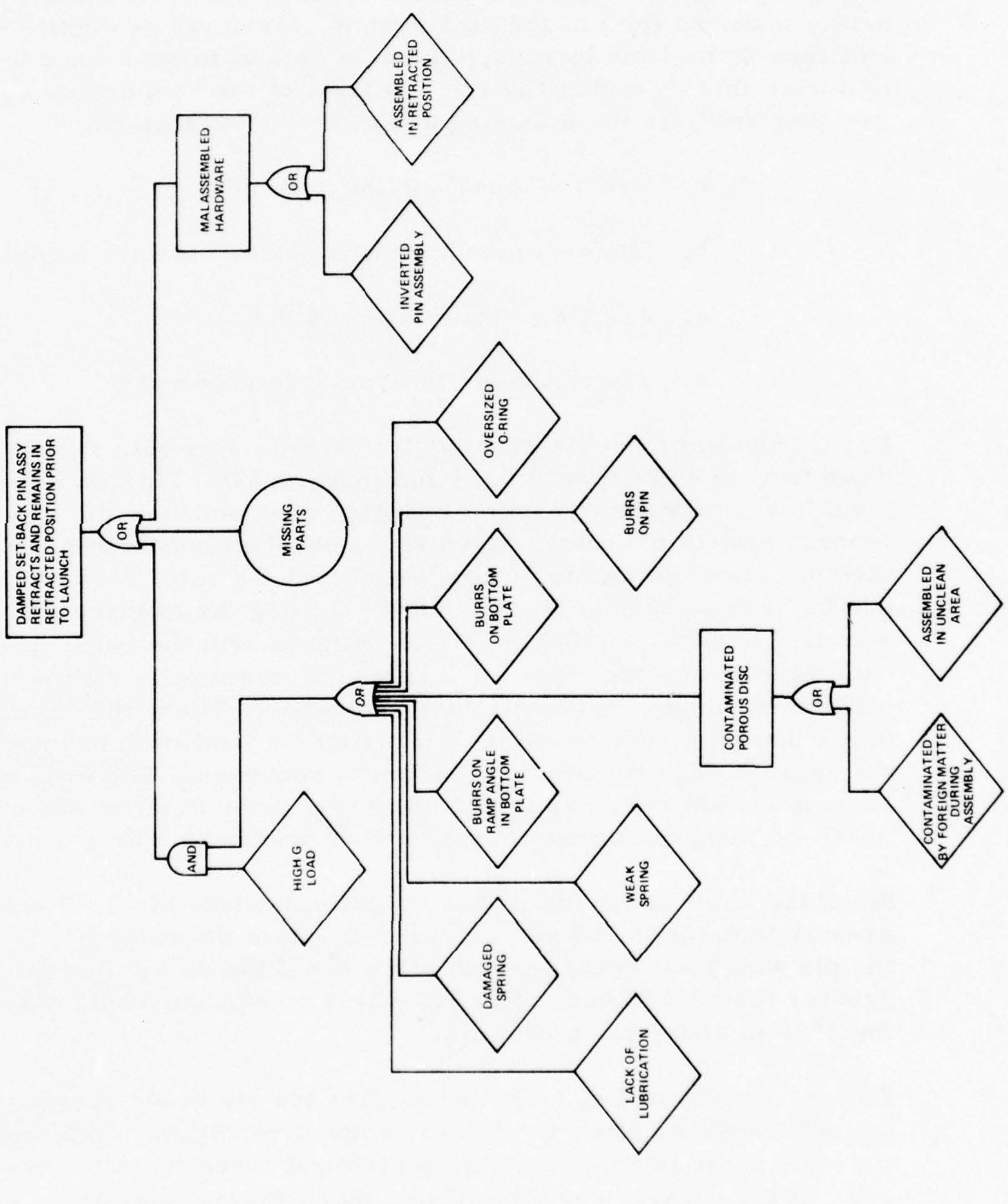

Figure 21. Safety Fault Tree.

and the time for the projectile to fall from the upright position to the rolling position. The analysis presented in Appendix F illustrates one of several situations that a projectile could experience during handling.

The second situation that could occur during handling is that of a projectile that rolls down an inclined surface and somehow pivots and impacts onto its base, causing the damped set-back pin to be retracted and disengaging one safety features (pin) of the S&A device. Since the projectile has inertia it will take some time to reduce the spin rate at impact down to 1100 rpm. It is during this time that the rotor section of the S&A device will begin to arm. For this analysis the following assumptions were made:

a. Projectile rolls without slipping.

b. Mass moment of inertia same as solid cylinders.

c. Coefficient of friction is 0.8.

d. The threshold of arming is 1100 rpm.

For a 155mm projectile that has a 1500 rpm spin rate at impact the spin down time to 1100 rpm is 0.19 sec (Figure 22). This spin time of 0.19 sec would cause the rotor section to rotate over one-half the set-back pin diameter (approzimately 6° rotor movement is one-half pin diameter), which would then not allow the pin to be reengaged into the rotor for positive safing. This can be seen when Figure 23 is used. Taking the average spin-down of 1300 rpm (i.e., (1500 + 1100) ÷ 2), the time to arm the rotor is 1.08 sec. This time is to rotate the rotor 90°, although, essentially all the delay is accomplished in the gear train within 45° rotation. Then, the time to rotate 6° is 0.144 sec plus 10% for start up inertia or a total of 0.158 sec, which moves the rotor enough to not allow the pin to reengage. The drop condition to acquire a 1500 rpm spin (on 155mm) is a slope at some angle (67° on dirt) at which no slippage occurs during rolling and from a drop height of 69 ft.

Since the rotor is acted upon by centrifugal force for 0.19 sec, which is greater than the 0.158 sec required to rotate the rotor 6°, it was concluded the pin would not reengage into the rotor if the delay time on the pin was greater than 0.158 sec. The hazardous conditions would also hold true for the 175mm and 8-in. projectile.

For the 105mm and 4.2-in. projectiles the pin would reengage into the rotor for safe handling after a roll/base impact condition. This was true because the time the rotor is acted upon by centrifugal force (0.140 sec) is less than 0.158 sec. If the delay exceed this time, there would, however, be a safety hazard encountered.

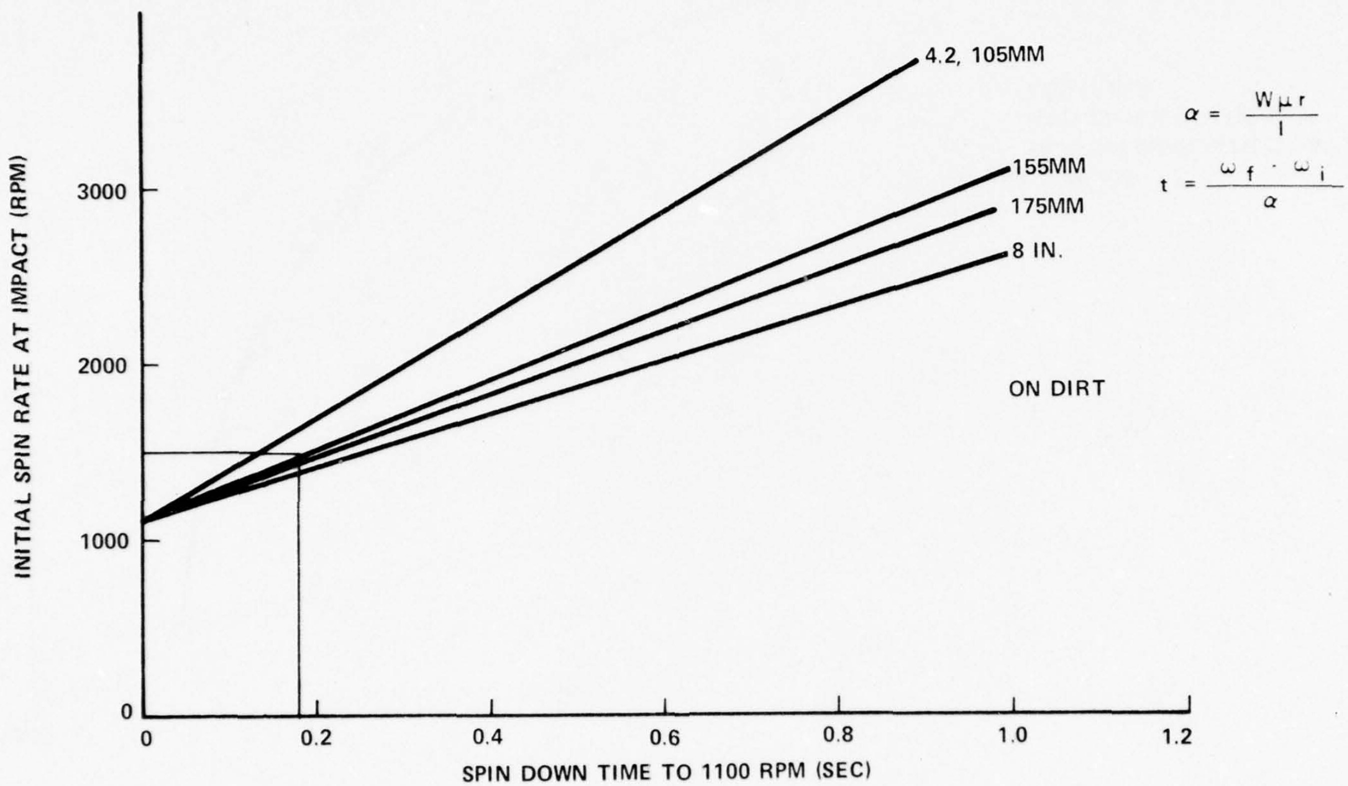

Figure 22. Projectile Spin Down Time.

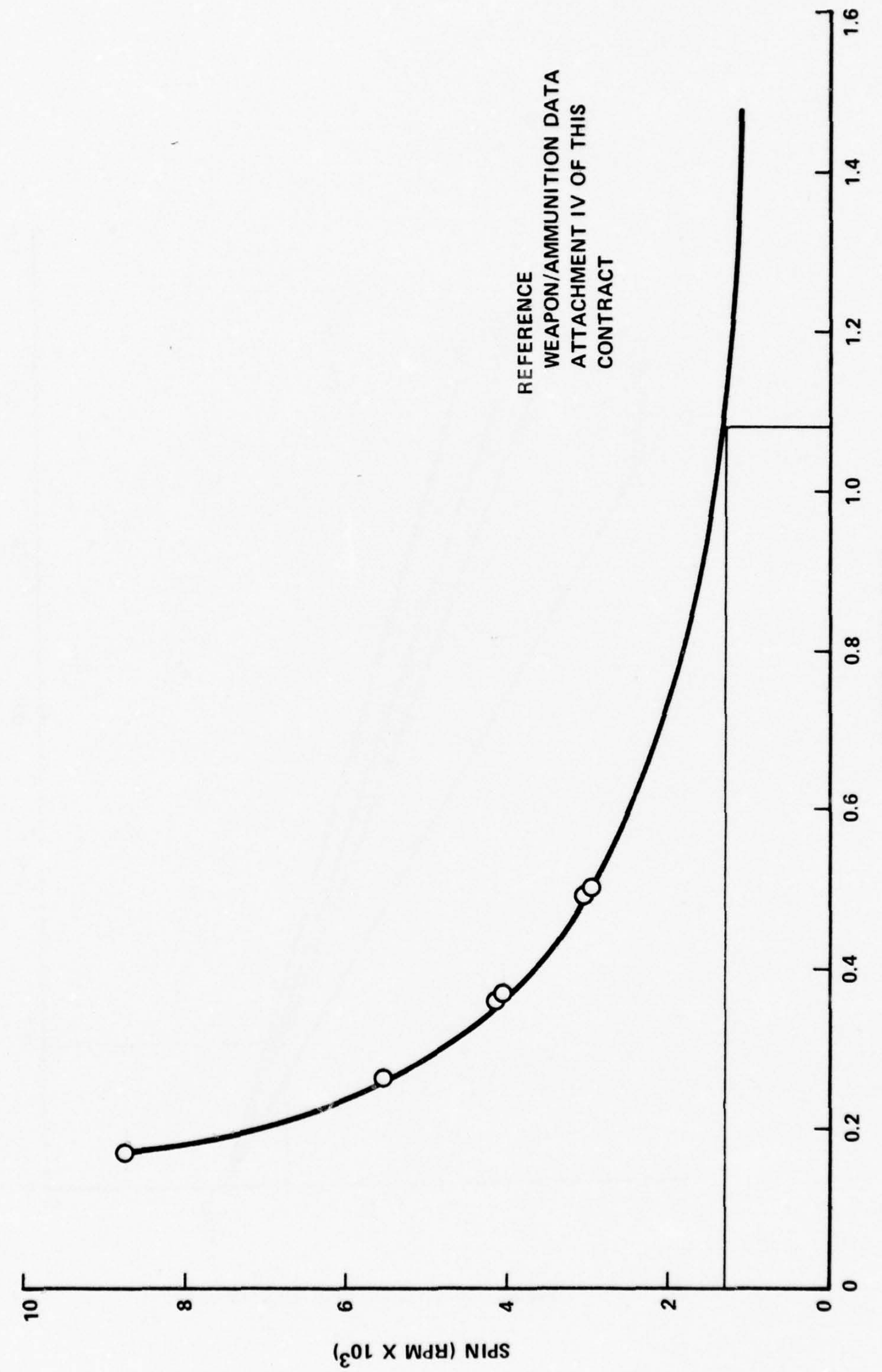

Figure 23. Spin Versus Arming Time.
(24 turns to arm)

5.4.2.2.3 Delay Time Consideration

Varying system parameters would produce nominal delays form a few milliseconds up to about one second. However, it was necessary to find the nominal time to provide the best compromise between reliability and safety. Figure 24 and Table 7 show many of the timing considerations when coupled to the S&A for the M739 PD fuze. (Figure 24 was constructed using the data from the M739 fuze specification and roll/drop base-impact analysis presented in Paragraph 5.4.2.2.2). From these data it appeared that a delay not to exceed 0.130 sec provided maximum safety at the expense of possibly degrading reliability by permitting the pin to drag on the underside of the rotor during arming. A delay in excess of 0.400 sec would have a minimal effect on reliability at the expense of handling safety. In any event, this delay must exceed 0.080 sec or the rotor would be relocked during launch amd would be a complete dud.

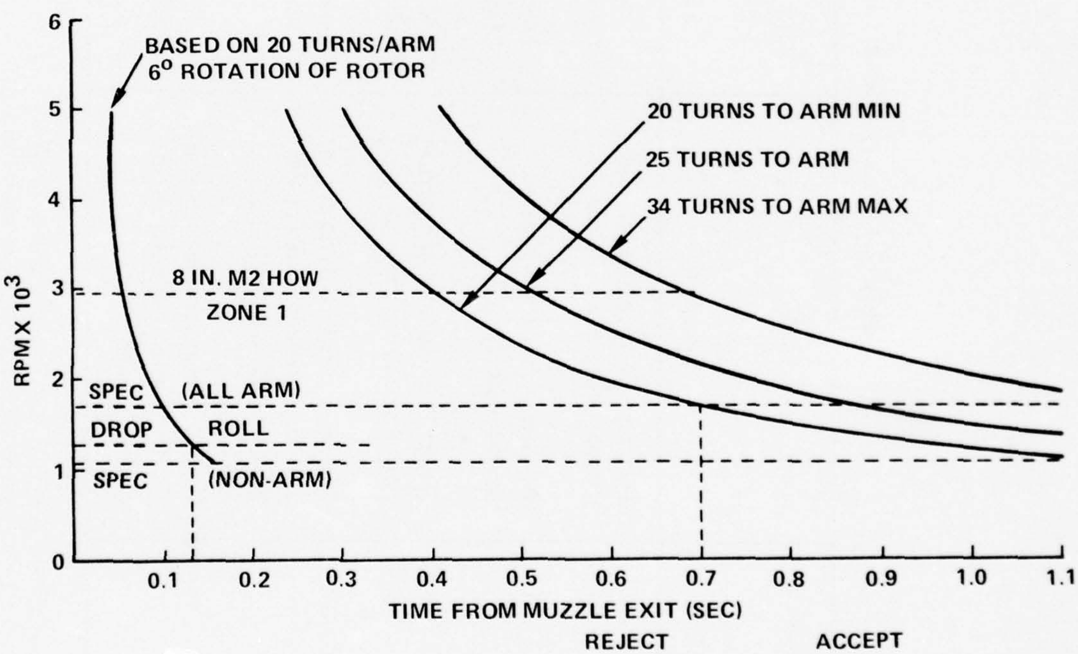

Figure 24. M739 PD Fuze Rotor (S&A) Arming Characteristics Based on Specification MIL-F-48277.

Table 7. Delay Time Considerations.

Possible Delay (sec)		Reason	Resultant Problem	Potential Correction
Min	Max			
0.030	-	Permit projectile to clear muzzle blast	Pin may reengage rotor (cause dud)	Lengthen delay
0.080	-	Permit 6° rotor turn avoid resafing	Pin drags on rotor affect reliability	Note a, b, or c
-	0.130	Permit resafing if ramp-roll experienced	Pin drags on rotor affect reliability	Note a, b, or c
-	0.400	Permit minimum tactical arming without affect on rotor reliability	Lose handling safety under ramp-roll	Note a, b, or c
-	0.700	Permit maximum tactical arming without affect on rotor reliability	Lose handling safety under ramp-roll	Note a, b, or c

[a] Increase pin dependency for withdrawal on Δv so it will withdraw under actual launch only (discriminate between G-T of drop versus launch).

[b] Increase pin delay dependency of centrifugal force (and resultant friction), so delay would be longer under 3000 rpm than under 1300 rpm. Therefore, pin would return much sooner under ramp-roll than under firing.

[c] Provide clearance track for returned pin on underside of rotor.

5.4.2.2.4 G-T Product Discriminator

The comparison of G-T products (acceleration x time) for various extremes in handling and launch environments in relation to that currently achievable in the damped set-back pin system is presented in Table 8. This was done to determine if the damped set-back pin system could discriminate between the two regimes. The drop test values were obtained from a summary report published by the Rheem Manufacturing Co., Downey, California, on 30 September 1975, titled: "Accelerometer and Drop Test Studies and Recommendations for Revision on MIL-STD-302." The data showed at least an order of magnitude difference between the G-T products between handling and launch environment, such that a set-back pin capable of discriminating between the two levels should be amply safe as well as reliable. The resultant response of the damped set-back pin in the 155mm Howitzer was shown to be not adequately safe, in that the G-T of 2.7 for Zone 1 was comparable to the handling environment (G-T of 2 to 6) even though at Zone 8 its response was well above the G-T of 6 for handling. This means that either the G-bias level of 300 should be increased or else increase the change in velocity to which the pin responds.

5.5 TEST RESULTS

5.5.1 MIL-STD-331

Fifty-one damped set-back pin assemblies were assembled and tested using MIL-STD-331 as a guide. The test flow block diagram is shown in Figure 25. Figure 26 shows the delay time measuring set-up. (Also see Appendix C Figure C-40)

The damped set-back pin assemblies successfully passed the four chosen tests: jolt, jumble, 40-ft drop, and transportation vibration (see Table 9).

A statistical analysis of correlating the independent and dependent variable was not attemped because of the data of delay times with independent variables showed virtually no correlation as can be seen in the scattergrams shown in Figure 27. This is contrary to the earlier parametric study conducted in this program. The lack of correlation between the experimental and theoretical is that the parametric study was based upon a deterministic model. It is obvious that there are one or more uncontrolled and unmeasured factors causing random deviations much larger than the effects of the controlled factors. Resources are not currently available for the determination of these factors.

Table 8. G-T Comparisons.

	Ammunition Drop Test Environment		Comparison with Launch Environment			Comparison with Damped Set-Back Pin Response (CSMP)	
Ammunition	81mm Mortar	2.75-in. Rocket	105mm XM204 (M1)	4.2-in. Mortar (M30)	4.2-in. Mortar (M30)	155mm Howitzer XM198 (XM549)	155mm Howitzer XM198 (XM549)
Zone	-	-	8	10	5	8	1
Muzzle Velocity (fps)	-	-	2170	480	357	2250	700
Attitude	Base down bare	Base down bare	-	-	-	-	-
Height (ft)	100	25	-	-	-	-	-
Impact Medium	Steel	Mud	-	-	-	-	-
Peak Acceleration (g)	18,000	14	18,060	3000	2130	14,500	1828
Pulse Duration (sec)	0.00031	0.14	0.009	0.0125	0.0155	0.0008	0.0015
G-T (Approximate)	6.0 (max)	2.0 (min)	162 (max)	37	33 (min)	11.6 (max)	2.7 (min)

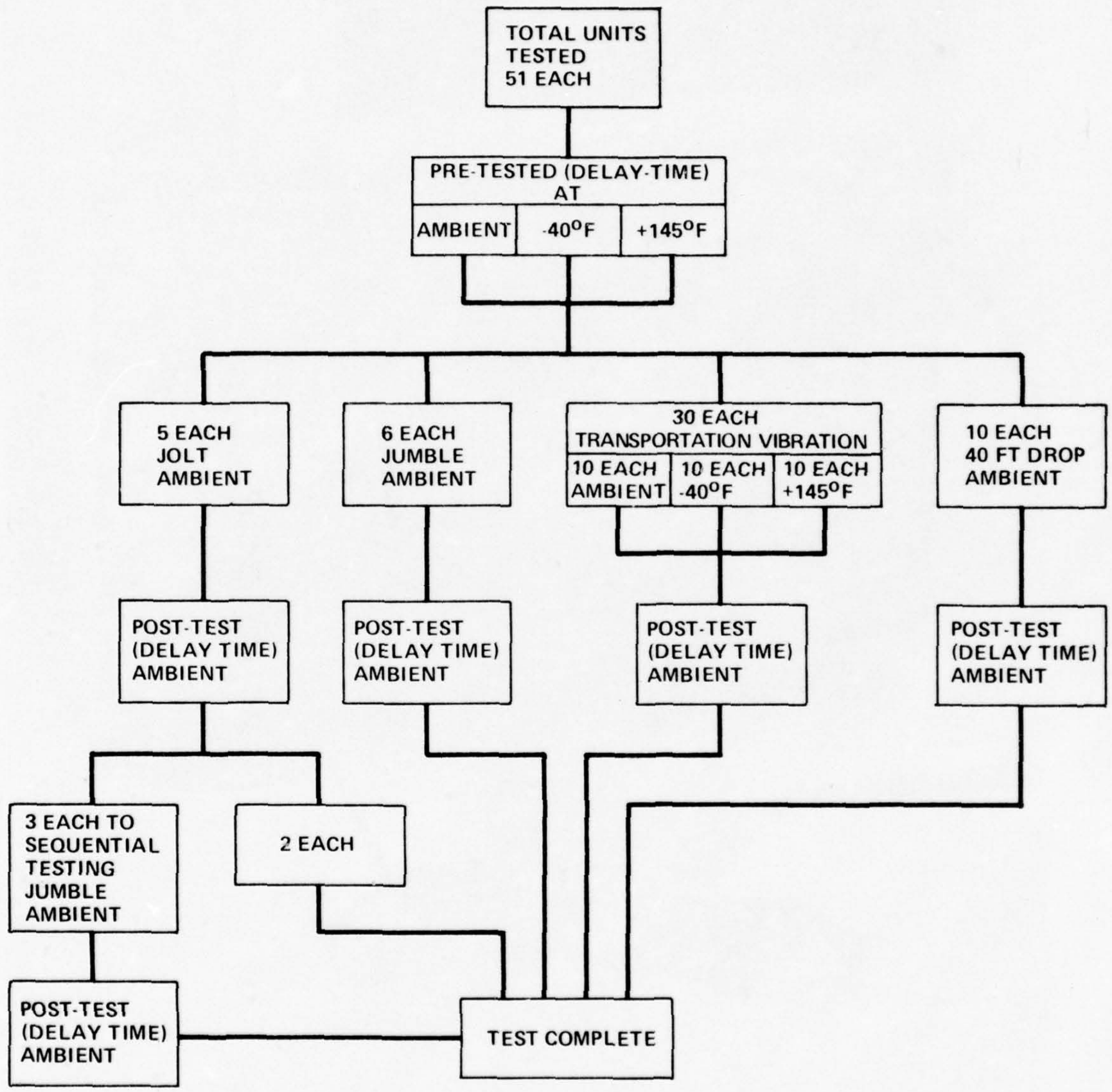

Figure 25. Test Block Flow Diagram.

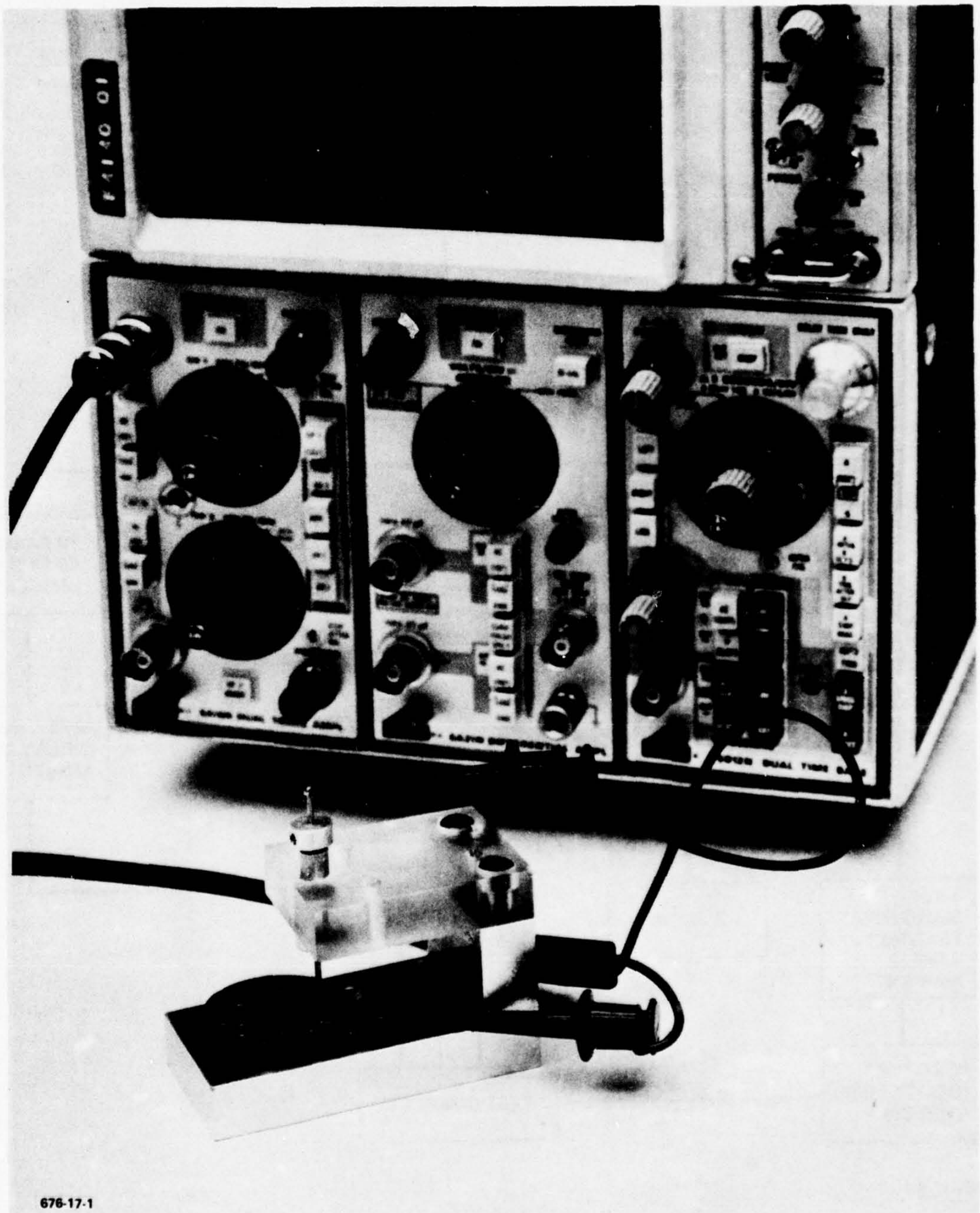

Figure 26. Delay Time Test Fixture Set-Up.

Table 9. Delay Time Test Data.

Unit No.	Cavity Diameter (in.)	O-Ring Diameter (in.)	Density (lb/in.^{3})	Flow Rate (cc/sec)	Spring Force (gm) 0.150 In. Length	Spring Force (gm) 0.062 In. Length	Pre-Test Delay Time (msec) 70°F	Pre-Test Delay Time (msec) +145°F	Pre-Test Delay Time (msec) -40°F	Type Test	Post-Test Delay Time (msec)	Pin Weight (gm)	Force to Depress Pin (gm)	Remarks
1000[a]	0.133	0.138	0.2072	0.1745	36	48	142.66	45.75	76.61	Jumble	70.00	-	44	Disassembled
1001[a]	0.133	0.138	0.2070	0.1589	32	43	236.54	250.00	227.45	TV 70	215.38	-	46	
1002[a]	0.133	0.139	0.2066	0.1860	32	43	148.62	127.72	158.38	TV 70	122.46	-	46	
1003[a]	0.133	0.138	0.2172	0.0793	32	43	138.03	124.32	153.40	Jumble	140.11	-	50	
1004[c]	0.133	0.139	0.2058	0.1043	32	43	208.27	56.10	142.23	Jumble	201.30	-	46	
1005[c]	0.133	0.138	0.2074	0.1120	32	43	821.49	482.98	712.37	TV 70	466.00	-	52	
1006[a]	0.133	0.136	0.2016	0.1233	34	44	47.02	40.00	306.00	TV 70	28.52	-	46	
1007[c]	0.132	0.138	0.1948	0.1430	31	41	150.22	111.21	144.08	TV 70	105.43	-	52	
1008[a]	0.133	0.138	0.2051	0.1255	34	44	139.87	127.70	157.16	TV 70	120.61	-	46	
1009[c]	0.133	0.138	0.2033	0.1153	33	45	1068.21	329.45	615.00	TV 70	273.59	-	50	
1010[a]	0.133	0.138	0.2043	0.1189	33	43	550.17	206.67	366.45	TV 70	246.39	-	54	
1011[c]	0.133	0.138	0.1976	0.1189	35	47	443.71	150.00	417.00	TV 70	136.22	-	50	
1012[a]	0.133	0.138	0.2075	0.1089	33	43	969.06	655.86	875.45	TV 70	192.54	-	54	
1013[a]	0.133	0.138	0.2114	0.1214	33	43	317.77	150.00	247.57	TV -40	227.85	-	54	
1014[c]	0.133	0.138	0.2078	0.0822	33	45	162.24	178.76	153.64	TV -40	116.58	-	60	
1015[a]	0.133	0.138	0.2032	0.1104	33	45	246.35	83.75	190.62	TV -40	47.34	-	58	
1016[c]	0.133	0.138	0.2046	0.1344	33	45	476.39	354.41	196.64	TV -40	419.68	-	56	
1017[a]	0.133	0.138	0.2005	0.1400	33	43	56.55	35.94	32.26	TV -40	42.29	-	56	
1018[a]	0.133	0.138	0.2026	0.1504	33	45	324.98	214.94	221.15	TV -40	150.07	-	54	
1019[c]	0.133	0.138	0.2009	0.0943	33	45	165.00	97.52	55.34	TV 145	45.56	-	58	
1020[c]	0.133	0.138	0.2067	0.0925	33	45	237.73	190.00	175.00	TV 145	148.94	-	54	
1021[c]	0.133	0.138	0.2034	0.0876	33	45	167.89	145.00	124.28	TV 145	170.19	-	42	
1022[a]	0.133	0.138	0.1970	0.1811	33	45	372.66	219.84	351.59	TV -40	315.90	0.1141	52	
1023[c]	0.133	0.138	0.2025	0.0987	33	45	98.22	137.12	131.45	TV -40	145.01	0.1151	50	
1024[a]	0.133	0.138	0.2074	0.1270	33	45	655.34	731.04	706.63	TV -40	503.59	0.1156	52	
1025[a]	0.133	0.138	0.2033	0.1136	33	45	92.31	120.45	43.77	TV -40	98.18	0.1155	58	
1026[c]	0.133	0.138	0.2078	0.1322	32	42	471.88	742.93	160.20	TV 145	355.83	0.1151	54	
1027[a]	0.133	0.138	0.2118	0.1502	32	42	318.31	420.22	311.11	TV 145	210.00	0.1135	56	
1028[a]	0.133	0.138	0.2090	0.1621	33	45	281.81	283.14	287.09	TV 145	249.12	0.1165	54	
1029[c]	-	-	Lost	-	-	-	-	-	-	-	-	-	-	
1030[a]	0.133	0.138	0.2067	0.1426	35	46	477.41	751.64	162.08	TV 145	360.00	0.1145	58	
1031[c]	0.133	0.138	0.2066	0.1537	33	45	135.64	107.81	118.45	TV 145	121.49	0.1137	54	

Table 9. Delay Time Test Data. (Continued)

Unit No.	Cavity Diameter (in.)	O-Ring Diameter (in.)	Density (lb/in.^{3})	Flow Rate (cc/sec)	Spring Force, (gm) 0.150 In. Length	Spring Force, (gm) 0.062 In. Length	Pre-Test Delay Time (msec) 70°F	Pre-Test Delay Time (msec) +145°F	Pre-Test Delay Time (msec) -40°F	Type Test	Post-Test Delay Time (msec)	Pin Weight (gm)	Force to Depress Pin (gm)	Remarks
1032[a]	0.133	0.138	0.2038	0.1318	35	46	400.51	630.56	135.97	TV 145	302.01	0.1144	68	
1033[c]	0.133	0.138	0.2070	0.1291	35	46	727.40	619.43	376.51	TV 145	460.59	0.1128	66	
1034[c]	0.133	0.138	0.1965	0.1453	35	46	49.66	54.95	61.48	Jumble	55.36	0.1166	54	
1035[c]	0.133	0.138	0.2102	0.1373	35	46	271.83	273.12	276.93	Jumble	240.30	0.1159	62	
1036[b]	0.133	0.138	0.2055	0.0812	35	46	448.95	635.32	516.39	Jolt	410.07	0.1162	60	Time after Jumble 578.12
1037[c]	0.133	0.138	0.2032	0.1022	35	46	110.48	230.11	363.63	Jolt	119.35	0.1154	54	Time after Jumble 102.09
1038[c]	0.133	0.138	0.2019	0.1510	35	46	262.92	283.88	167.53	Jolt	237.39	0.1134	54	Time after Jumble 207.47
1039[a]	0.133	0.138	0.2078	0.1276	35	46	108.67	140.82	73.78	Jolt	136.19	0.1148	54	
1040[c]	0.133	0.138	0.2086	0.1228	34	45	360.94	375.00	310.51	Jolt	417.47	0.1150	54	
1041[a]	0.133	0.138	0.2071	0.1161	34	45	625.35	596.74	471.18	40 ft	537.90	0.1145	64	45° Nose down
1042[c]	0.133	0.138	0.2007	0.0953	34	45	303.07	400.10	296.21	40 ft	220.56	0.1159	48	45° Nose down
1043[c]	0.133	0.138	0.2012	0.1356	34	45	124.86	451.91	234.61	40 ft	81.98	0.1156	50	Horizontal
1044[a]	0.133	0.138	0.1994	0.1232	34	45	362.77	398.38	388.41	40 ft	214.40	0.1149	56	Horizontal
1045[c]	0.133	0.138	0.2040	0.0973	34	45	323.15	323.30	306.43	40 ft	217.00	0.1160	56	45° Base down
1046[c]	0.133	0.138	0.2078	0.1182	34	45	444.87	700.40	151.03	Jumble	335.46	0.1170	56	
1047[a]	0.132	0.138	0.2002	0.1586	34	45	709.97	604.59	367.49	40 ft	449.65	0.1165	58	Nose down
1048[c]	0.132	0.138	0.2026	0.1692	34	45	278.08	214.24	475.07	40 ft	199.35	0.1144	56	Nose down
1049[a]	0.133	0.138	0.2044	0.0862	34	45	166.04	130.00	104.07	40 ft	175.00	0.1169	58	45° Base down
1050[a]	0.133	0.138	0.2025	0.1883	34	45	288.86	356.88	228.25	40 ft	452.00	0.1125	56	Base down
1051[c]	0.133	0.138	0.2017	0.1323	34	46	164.80	156.99	175.10	40 ft	100.16	0.1155	56	Base down
1052[a]	0.133	0.138	0.2102	0.0946	34	46	344.25	411.81	361.85	-		0.1162	64	Extra hardware
1055[c]	0.133	0.138	0.2058	0.0917	34	46	125.57	288.42	150.97	-		0.1175	58	Extra hardware

NOTES:
[a]Damped set-back pin length = 0.228 in.
[b]Damped set-back pin length = 0.227 in.
[c]Damped set-back pin length = 0.229 in.

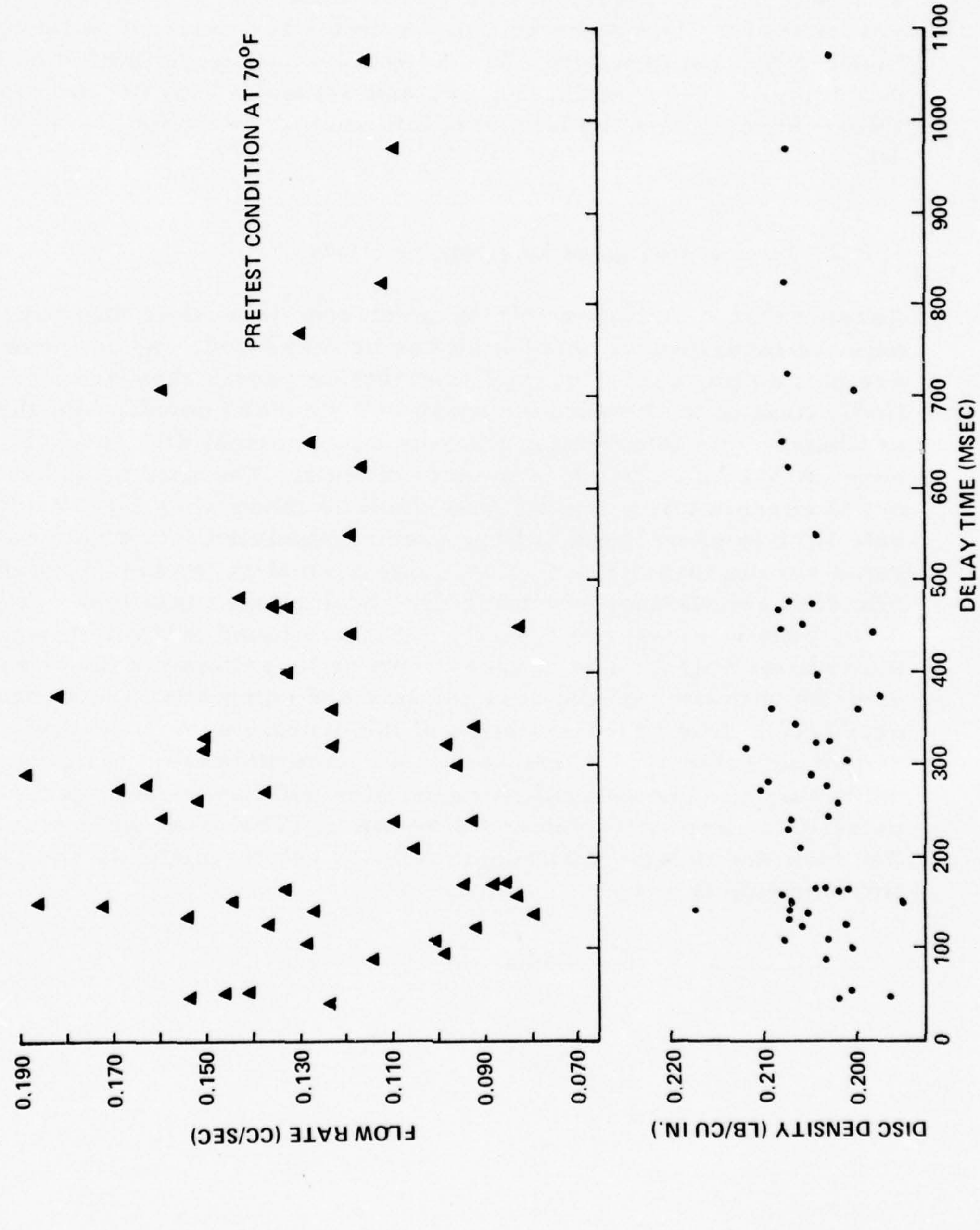

Figure 27. Scattergram of Delay Time.

A histogram was constructed of delay times at the three temperature conditions of: +70°F, -40°F, and +145°F. These are presented in Figure 28. It can be seen that the delay times are not a normal distribution but are skewed (log-normal) with geometric mean times calculated to be of 252.75 msec, 211.45 msec, and 229.06 msec at +70°, -40°, and +145°F, respectively. The geometric mean time after environmental testing was found to be 179.74 msec. The delay time data were plotted on log-normal graph paper (Figures 29, 30, 31, and 32) and a best fit line was constructed. Using these curves the following information was obtained as shown in Table 10.

5.5.2 Interpretation of Log Normal Data

Assume that it is impossible tc measure delay time directly. Instead, only the logarithm of delay time can be measured. When these logarithms are plotted on regular normal distribution paper, they produce a straight line. Next is to compute the mean and standard deviation of these logarithms and handle this information like any other normal distribution. Unfortunately, none of this information is in units of time. The antilogarithm is required, but to correct this situation care must be taken when this is done. The only safe time is when the data have been manipulated into a comulative frequency value versus logarithmic value. Log normal paper (on which the antilogarithmic data are plotted) automatically accomplishes this task. In this case, the delay time is measured directly but it was found that the times were not normally distributed. The curves drawn on logarithmic normal paper can be read directly with time on the vertical axis and cumulative frequency on the horizontal axis. The characteristics of the underlying normal distribution is presented on Table 10. These values are computed from the logarithms of the delay times. The delay time associated with the mean logarithmic value is actually the expected median delay time. (The delay time above which half the recorded delay times should fall and below which half the recorded delay times should fall.)

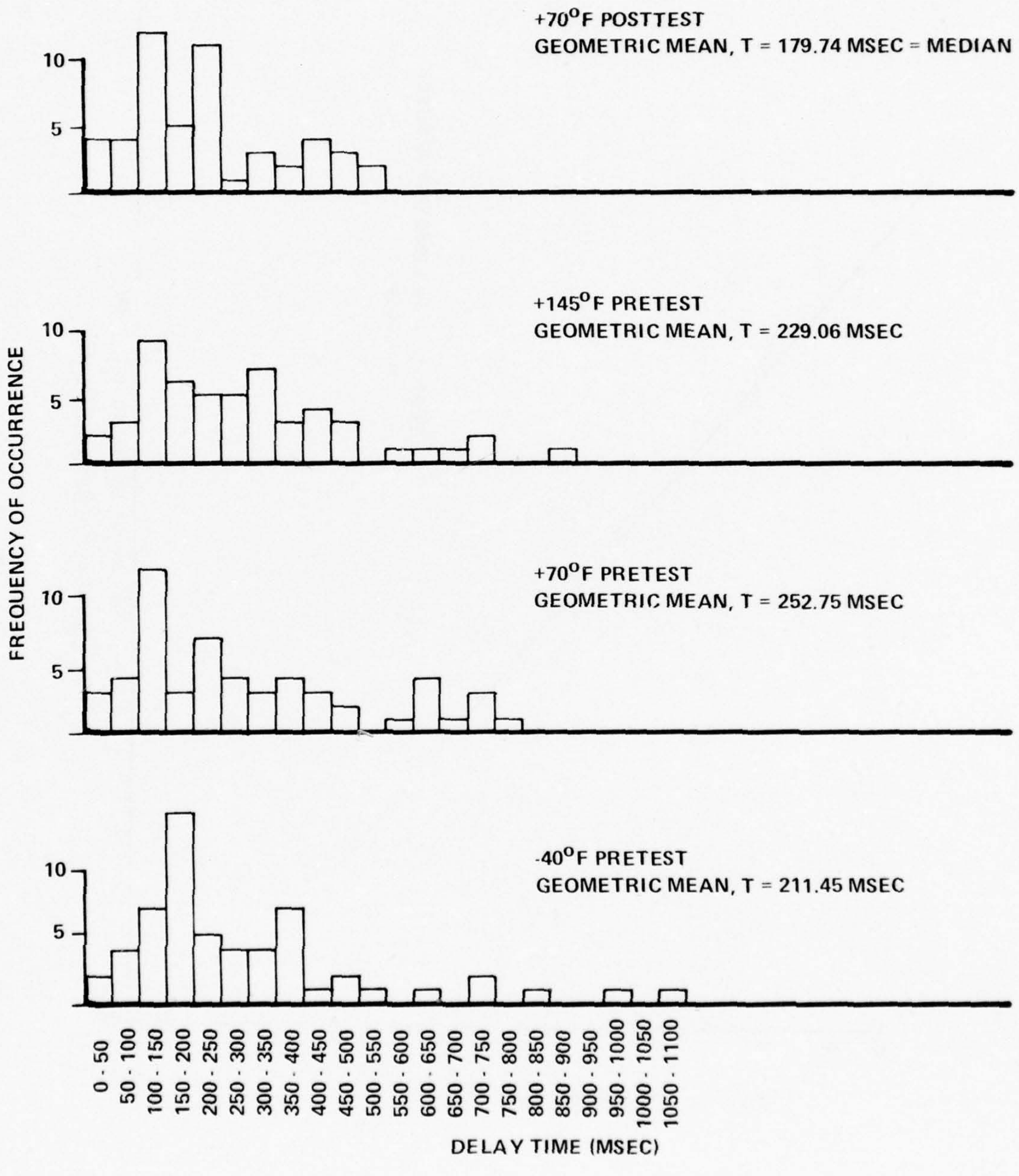

Figure 28. Histogram of Delay Time.

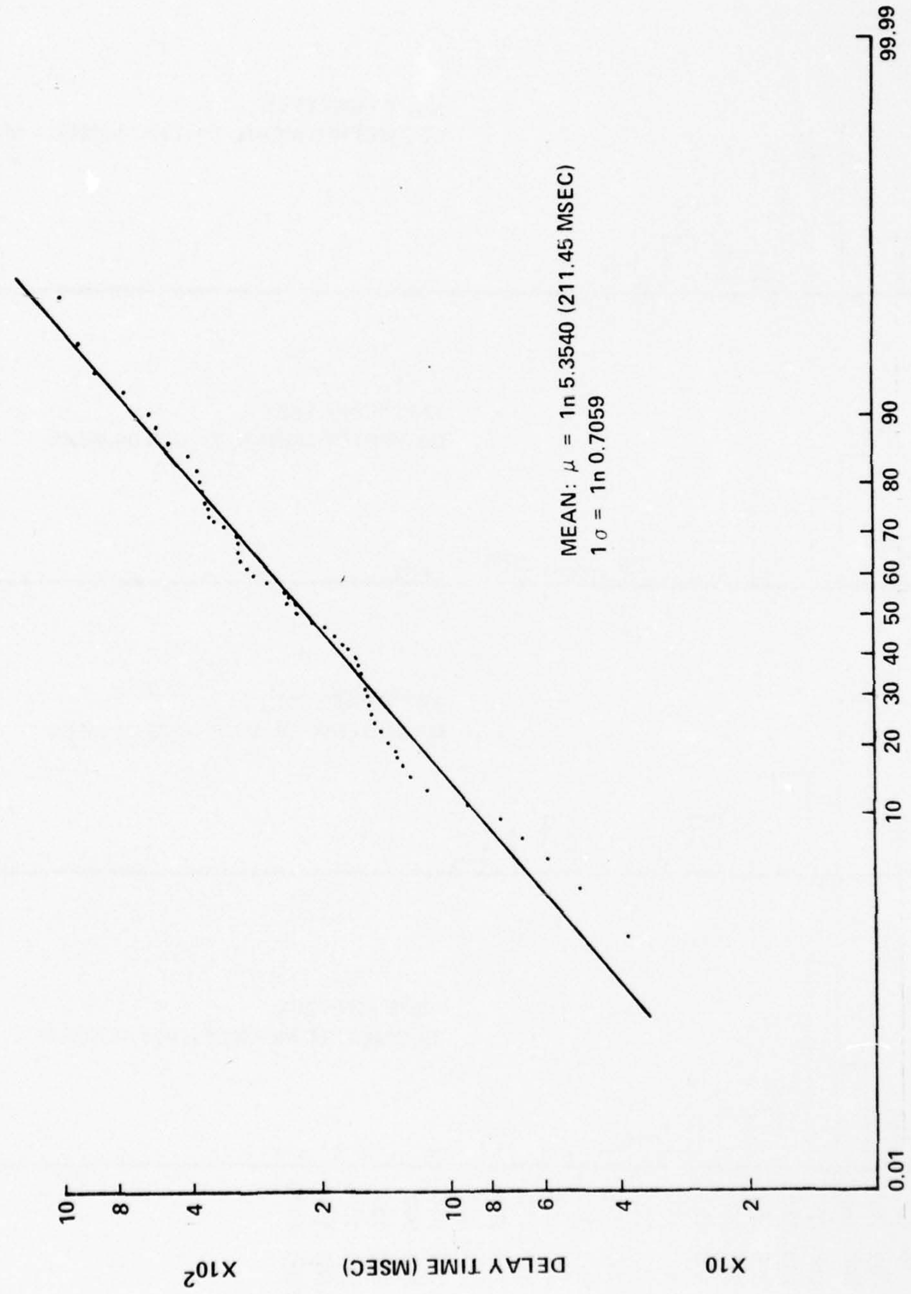

Figure 29. Cumulative Percent of Delay Time at +70°F.

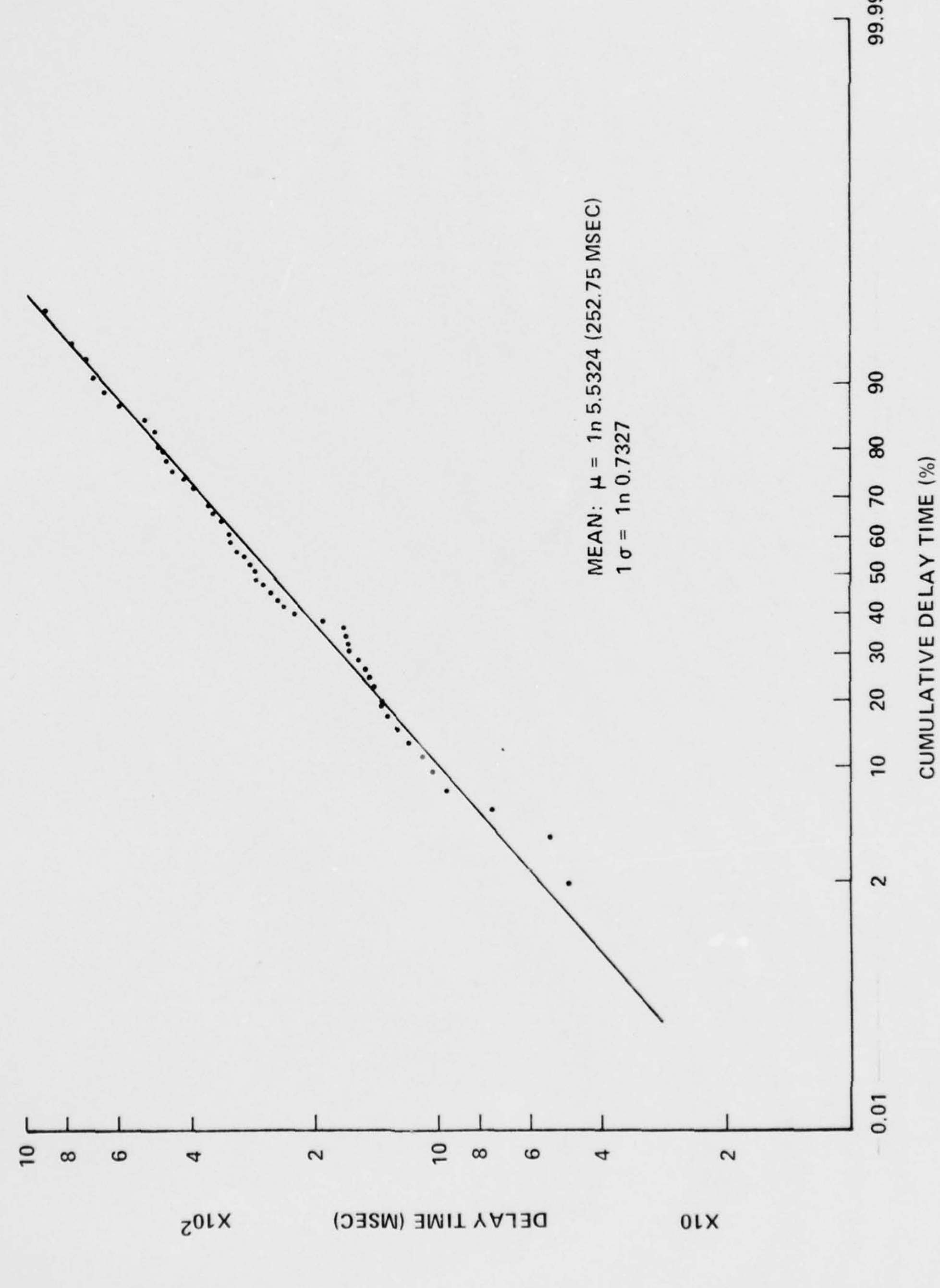

Figure 30. Cumulative Percent of Delay Time at -40°F.

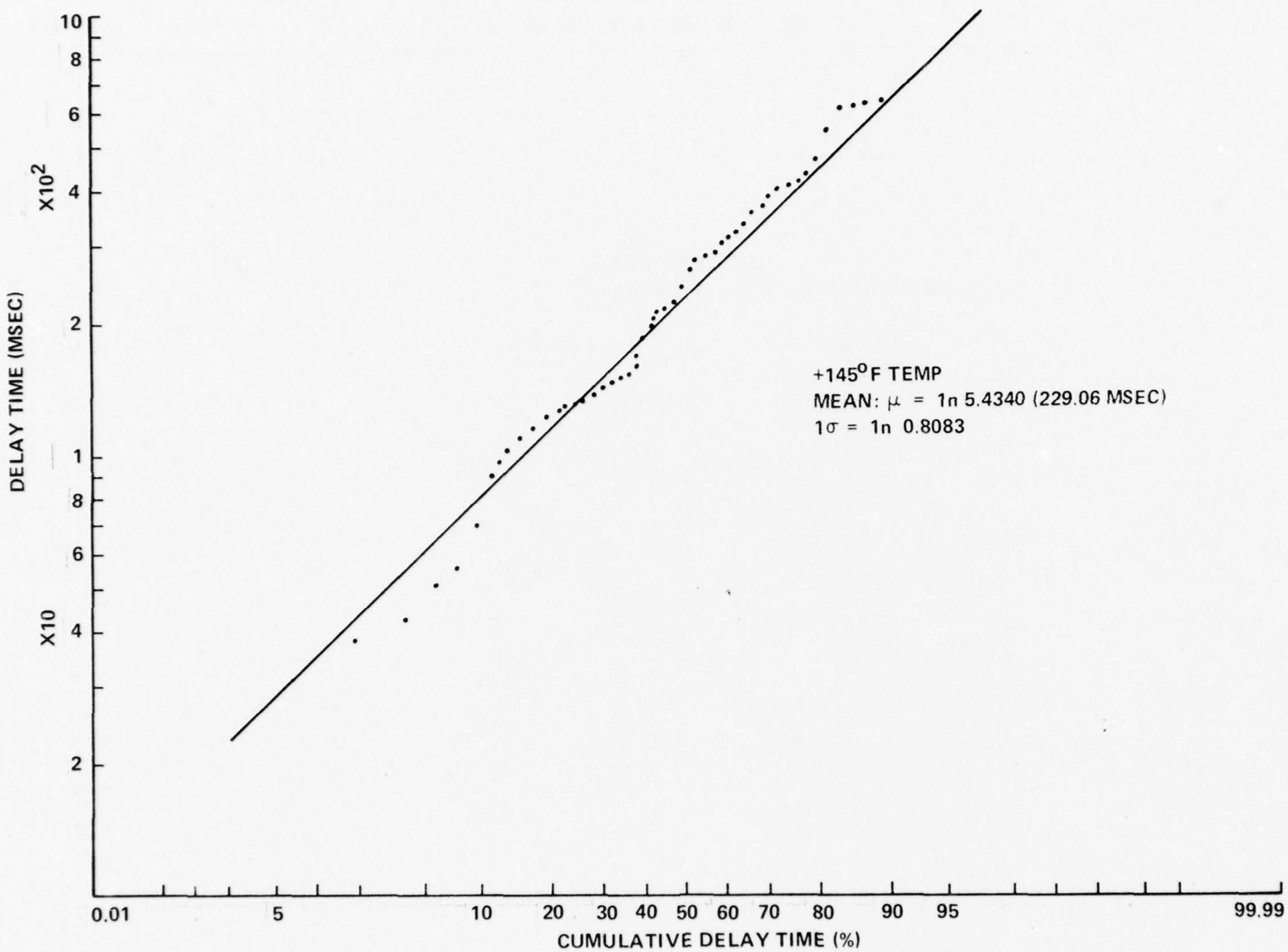

Figure 31. Cumulative Percent of Delay Time at +145°F.

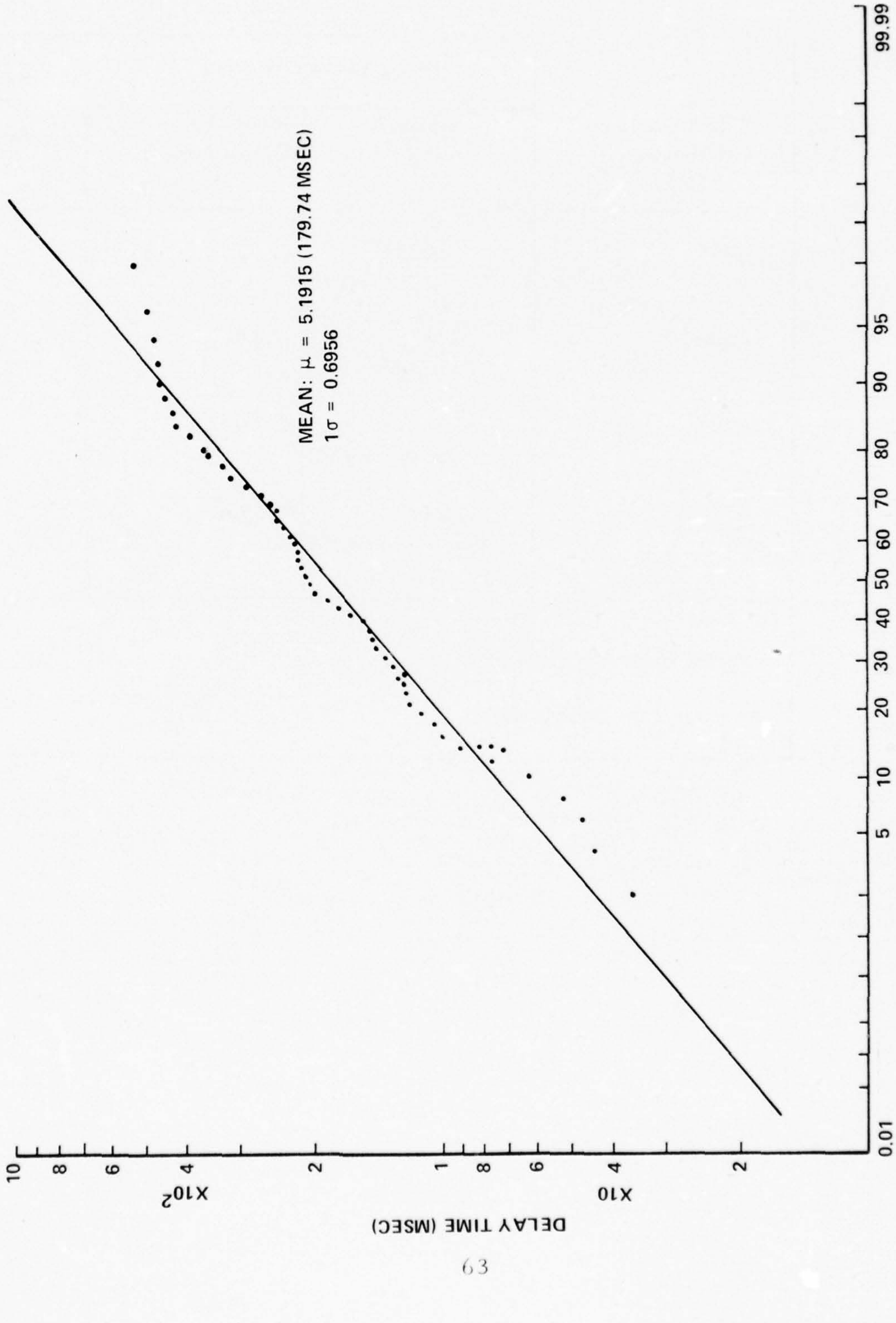

Figure 32. Posttest Cumulative Percent of Delay Time at 70°F.

Table 10. Test Results.

Temperature Condition (°F)	Log_e (delay time)		S&A Devices with a Delay Time of 80 - 1000 msec (%)
	Mean, μ	Standard Deviation, σ	
+70*	5.5324 (257.75 msec)	0.7327	91
-40*	5.3540 (211.45 msec)	0.7059	90.2
+145*	5.4340 (229.06 msec)	0.8083	86.5
+70**	5.1915 (179.74 msec)	0.6956	87.3

*Pre test delay time

**Post test delay time

Appendix A

REQUIREMENTS (SCOPE OF WORK)

To attain the objectives, AOMC shall perform the following:

a. Review the previous work on set-back pins and mathematical modeling as a means of determining the potential advantages of damping the forward motion. Retarding the motion opposite to the acceleration sensitive direction may be desirable to increase the reliability of operation (prevent reengagement during launch) as opposed to the adjustment of physical parameters in the design such as location of center of gravity, friction, inertia, coefficient or restitution, and centrifugal force. It is presently assumed that damping would retain the safety of the returnable type set-back pin, while achieving the reliability (lock-out) of one-way type set-back pin.

b. Generate several designs for damping the forward motion of set-back pins, based on pneumatic, mechanical, magnetic, hydraulic, and/or liquidic technologies. Eliminate all but one, or possibly two approaches by assessing each design for reliability of operation, safety, simplicity, producibility (automated assembly), and cost.

c. Prepare mathematical models of the dynamic response of the more optimum system, which will predict behavior of the motion of the set-back pin in both the rearward and forward directions.

d. Select one best approach and prepare sufficient models in order to evaluate performance by laboratory testing. These tests should include but not be limited to:

MIL-STD-331 Testing
- Test No. 101.1 - Jolt
- Test No. 102.1 - Jumble; test sequentially with Test 101.1
- Test No. 103 - 40-foot drop
- Test No. 104 - Transportation - vibration

Note: The above tests for safety and operability should include units conditioned at -40° and +145°F.

e. Fabricate and deliver to Picatinny Arsenal, fifty (50) complete sets of components either assembled to or for assembly to test vehicles (safe and arm devices of either M572E2 PD Fuzes or XM587 ET Fuzes).

f. Maintain a complete set of drawings in an up-to-date condition throughout the contract and deliver a complete set of reproducible drawings upon completion of contract.

Requirements:

a. The set-back pin shall be of the "returnable" type (reengages the stator after actuation), and be so designed to fit within the envelope constraints as shown in Figure A-1, regardless whether the design is modular or integral.

b. The set-back pin shall operate with very high reliability in a centrifugal force field within the limits of eccentricity shown in the enclosed figure.

c. The acceleration bias in the forward direction shall be compatible with the internal ballistic environment of the weapon cited in Table A-1 and must not be less than 35 g's. The preferred range is 500 g's if no compromise in the design results in order to provide adequate handling and transport safety. The minimum change in velocity required to actuate the system should be explored, 200 fps is suggested.

d. The response time for the initial withdrawal action (rearward stroke) under the extremes of ballistic environments specified in Table A-1 should not exceed 5 to 7 milliseconds, in order to be compatible with the internal ballistic conditions for the required weapons shown in Report No. DPS-2611, L. Hepner, Jan. '68, "Special Study of Set-Back and Spin for Artillery, Mortar, Recoilless Rifle and Tank Ammunition."

e. The damping effect should delay the set-back pin after full withdrawal in response to the internal ballistic environment until the rotor is sufficiently displaced to prevent reengagement. A nominal time of 125 milliseconds is suggested as a guide with 50 milliseconds as a minimum.

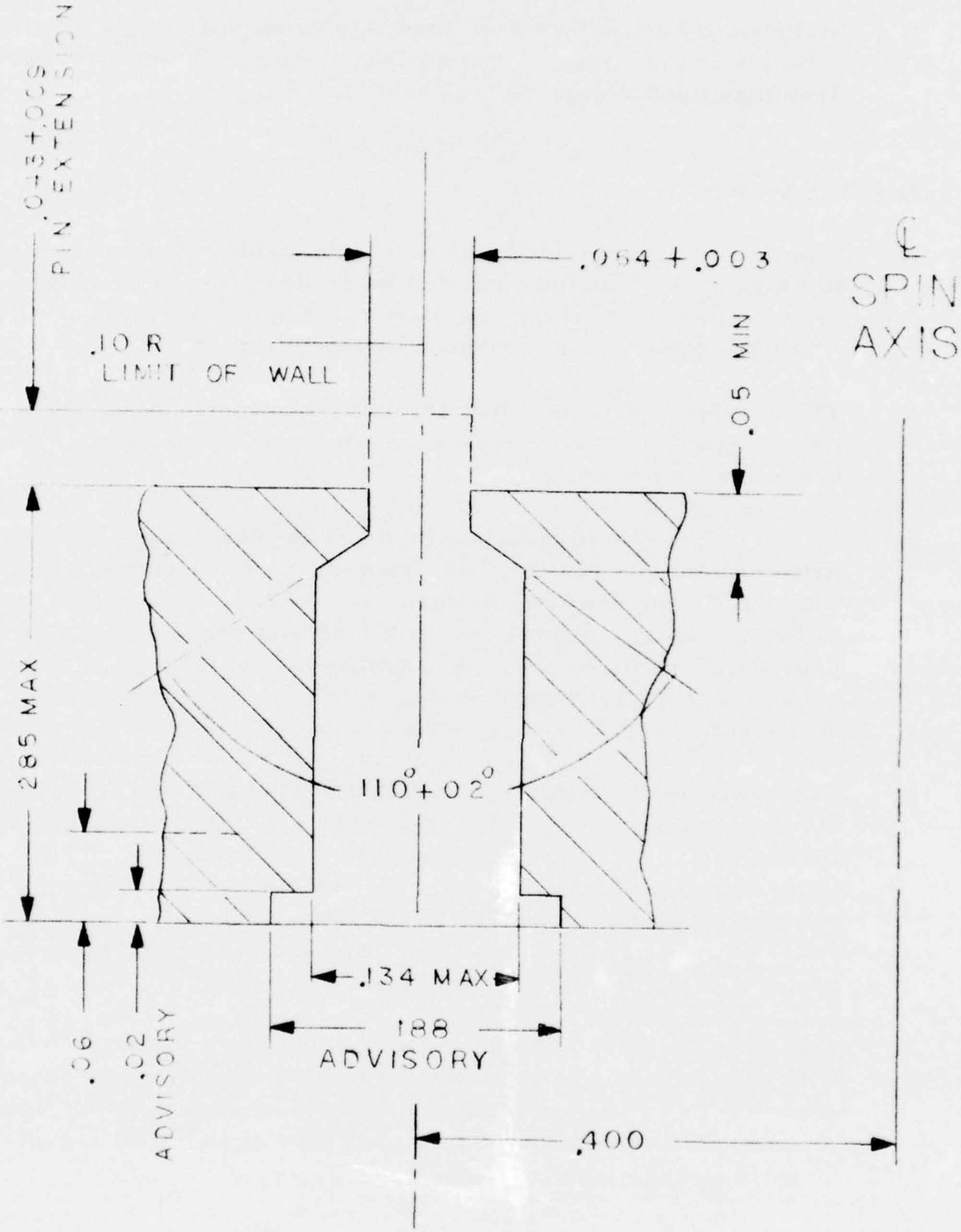

Figure A-1. Available Volume of Damped Set-Back Pin.

DATE: 27 June 19[illegible]

SHEET 1 of 2

Table A-1. Weapon/Ammunition Data (Nominal Values).

WEAPON					AMMO		PROPELLANT		MUZZLE VELOCITY	CHAMBER PRESSURE	ACCEL	SPIN
[illegible]	TYPE	MOD	CANNON	TWIST	PROJ	WT	ZONE	TYPE	FPS	PSI	G	RPM
105mm	Howitzer	M102	M103, M137, M165	1/35-1/18	HE M1	33	1	M67	673	8100	3330	6510
							7		1615	38000	15700	15626
					HE XM606	28.5	1	M84	420	5300	2496	4063
							8	M85	2200	42600	20061	21287
					RAP HE XM547E1	28.5	1	M84	420	-	-	-
							7	XM176	1800	31700	14929	17417
			M2A2, M49, M4A1	1/20	HE M1	33	1	M67	640	6900	2806	5574
							7		1525	34200	13910	13281
					HE XM606	28.5	1	M84	394	5300	2496	3431
							7		1653	28400	13374	14395
					RAP HE XM547E1	28.5	1	M84	394	5300	2496	3812
							7	XM176	1635	25000	11773	14239
			XM 204	1/35-1/18	HE M1	33	1			9100	3700	-
							8		2170	45000	18302	21000
155mm	Howitzer	M109	M126, M126A1	1/20	HE M107	95	1	M3	699	7000	1960	4124
							7	M4A1	1841	36400	11206	10861
		M109A1	M185, XM181, XM199	1/20	HE M107	95	1	M3	710	5000	1539	4189
							8	M119	2245	30200	9298	13245
		XM198	XM181, XM199	1/20	RAP HE XM549	96	1	XM164	700	6000	1828	4130

DATE: 27 June 197[illegible]

Table A-1. Weapon/Ammunition Data (Nominal Values). (Continued)

SHEET 2 of 2

WEAPON					AMMO		PROPELLANT		MUZZLE VELOCITY	CHAMBER PRESSURE	ACCEL	SPIN
[illegible]	TYPE	MOD	CANNON	TWIST	PROJ	WT	ZONE	TYPE	FPS	PSI	G	RPM
							8	XM123E2	1800-2250	35500-47500	11000-14500	10800-1350[illegible]
		M114A1	M1, M1A1, M45	1/25	HE M107	95	1	M3	680	5400	1680	3257
							7	M4A1	1850	36400	11206	8862
[illegible] in.	Howitzer	M110	M2, M2A1, M2A2, M47	1/25	HE M106	200	1	M1	829	9600	2413	2952
							8	XM161	2200	38500	9676	7920
				1/20	RAP HE XM650	200	1	M1	838	8000	2010	3771
							9	XM188	2530	39600	9953	11385
175mm	Gun	M107	M113A1	1/20	HE M437	147.75	1	M86A2	1675	10300	2600	8752
							3		3000	47200	11910	15675
[illegible].2 in.	Mortar		M30	0 TO 1/20	HE M329A1	26.23	5	M36A1	356	3300	2219	3051
							41	M36	983	14300	9617	8425

REFERENCE: 1. Artillery Ammunition Master Calibration Chart - TECOM Report #1375, Rev. 15 (Feb 1973)
2. Final Report - Study of Setback and Spin - Report #DPS-2611, L. Heppner (Jan 1968)

Appendix B

DRAWING PACKAGE

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8 7 6 5 4

NOTES:

1 SPEC MIL-A-2550 APPLY.
2 REMOVED.

3 STAKE CLOSURE DISC, ITEM 2, WITH 360 DEG INTERRUPTED STAKING.
4 APPLY SEALANT, ITEM 7, IN NOTED AREA.
5 SET-BACK FUNCTIONING TEST. THE SET-BACK PIN SHALL BE DEPRESSED UNTIL IT BOTTOMS. RELEASE AND MEASURE DELAY UNTIL PIN HAS RETURNED TO A 0.037 IN. MAX EXTENDED POSITION.

PART DASH NO.	NEXT QTY REQD PER ASSY	FINAL

8 7 6 5 4

2

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ITEM 4 WAS P/N 7500147	[illegible]	[illegible]
	B	REVISED AND REDRAWN SEE A CHANGE FOR WAS	[illegible]	[illegible]

QTY REQD -1	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPECIFICATION	ITEM NO.
1					8
1			SEALANT MIL-A-82484		7
1		7500190-1	SPRING, SET-BACK, DAMPED		6
1		7600113-1	PIN, SET-BACK, DAMPED SUBASSY		5
1		7500398-1	O-RING, DAMPED SET-BACK		4
1		7500367-1	PLATE, BOTTOM, MODIFIED		3
1		7500228-1	DISC, CLOSURE		2
		-1	ASSY		1

PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS ANGULAR
.XX ± .03 ±
.XXX ± .010
DO NOT SCALE DRAWING

TREATMENT

FINISH

CONTRACT NO.
DRAWN
CHECK
DESIGN 3/31/76
DESIGN ACTIVITY
CUSTOMER

AOMC AEROJET ORDNANCE AND MANUFACTURING COMPANY

TITLE
PIN, SET-BACK
DAMPED ASSEMBLY

SIZE	CODE IDENT NO.	DWG NO.
D	13309	7500225

SCALE | RELEASE DATE | SHEET 1 OF 2

PART DASH NO.	NEXT QTY REQD PER ASSY	FINAL	NEXT ASSY	USED ON
			APPLICATION	

SIMILAR TO | ACT. WT | CALC WT

2

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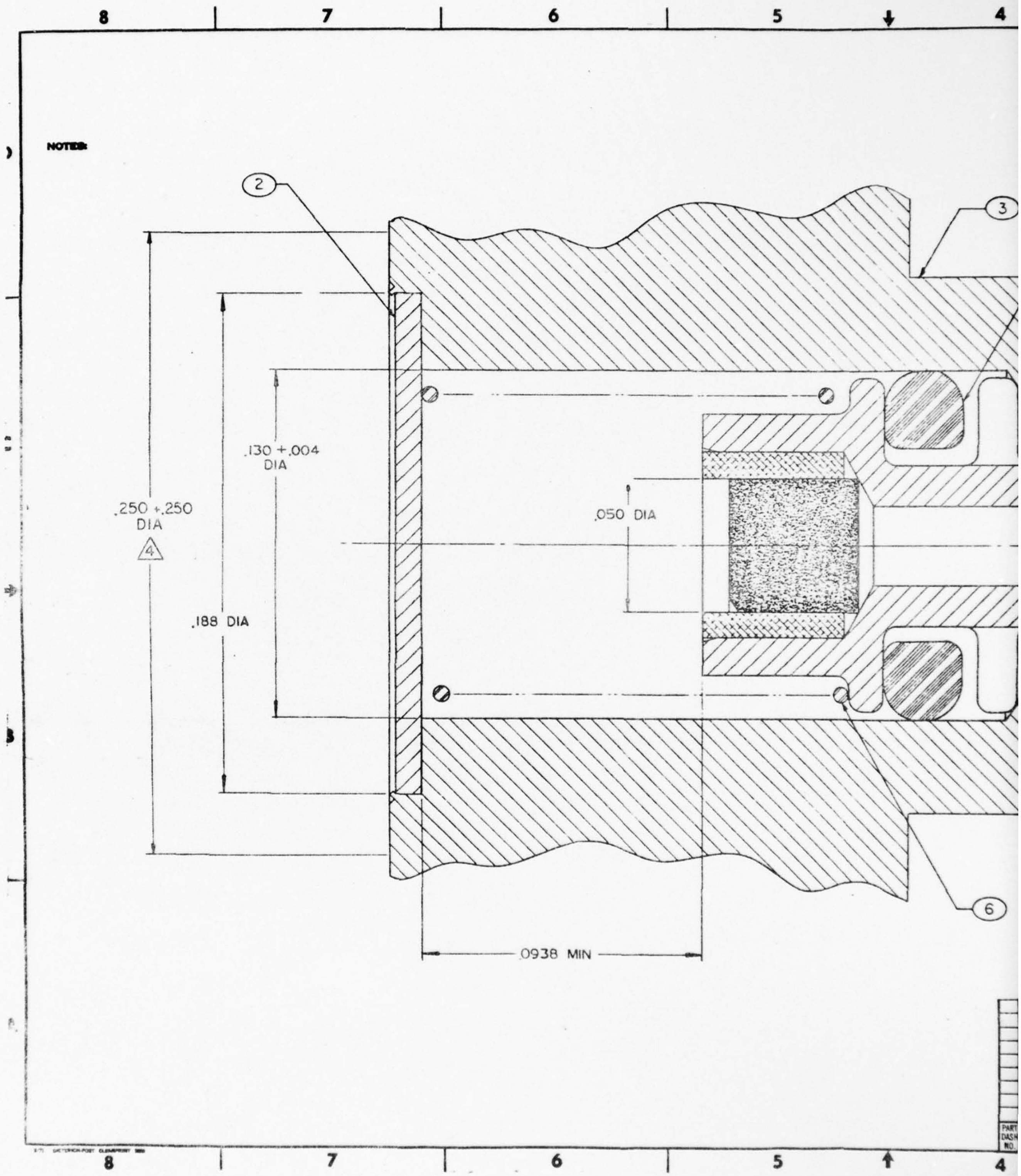
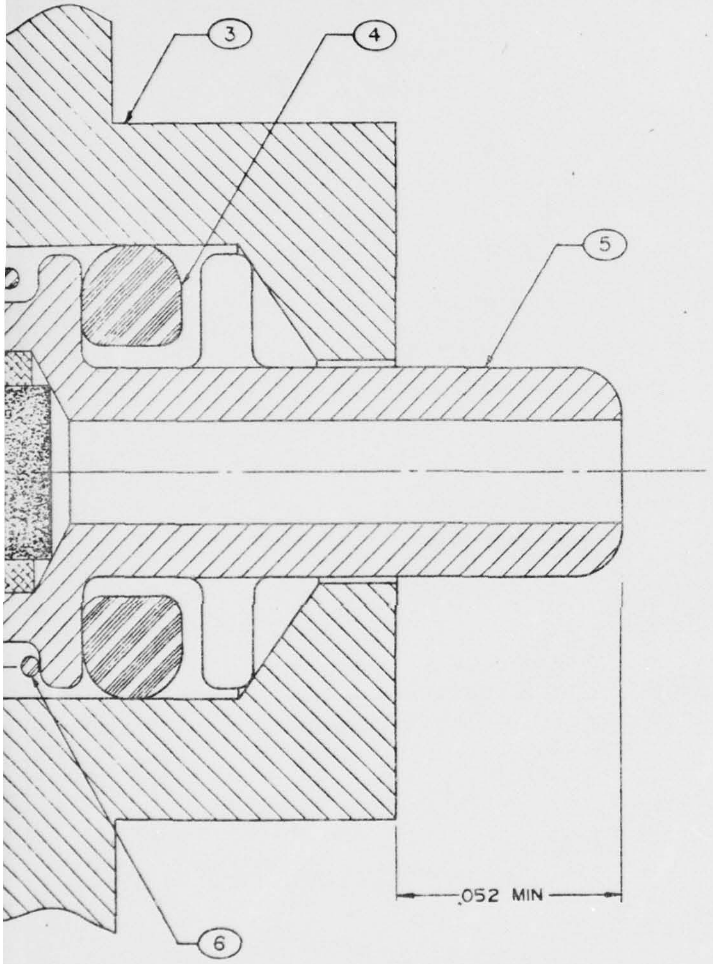




REVISIONS

ZONE | LTR | DESCRIPTION | DATE | APPROVED

QTY REQD | CODE IDENT | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | MATERIAL / SPECIFICATION | ITEM NO.

PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS ANGULAR
.XX ± .03
.XXX ± .010
DO NOT SCALE DRAWING

TREATMENT

FINISH

PART DASH NO. | NEXT | FINAL | NEXT ASSY | USED ON
QTY REQD PER ASSY | APPLICATION

SIMILAR TO | ACT. WT | CALC WT

CONTRACT NO.
DRAWN
CHECK
DESIGN
DESIGN ACTIVITY
CUSTOMER

AOMC AEROJET ORDNANCE AND MANUFACTURING COMPANY

TITLE
PIN, SET-BACK
DAMPED ASSEMBLY

SIZE D | CODE IDENT NO. 13309 | DWG NO. 7500225

SCALE | RELEASE DATE | SHEET 2 OF 2

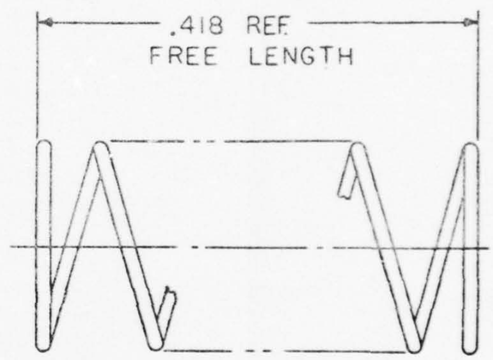
PRECEDING PAGE BLANK-NOT FILMED

4 3 2

ZONE

NOTES:

1 SPEC MIL-A-2550 APPLY.
2 WIRE DIA. .006 IN. REF.
3 SOLID HEIGHT .056 IN. MAX
4 .074 ±.007 LBS LOAD AT .150 IN. LENGTH.
5 .098±.010 LBS LOAD AT .062 IN LENGTH.
6 SPRING RATE .277 LBS/IN. REF.
7 DIRECTION OF HELIX OPTIONAL.
8 ACTIVE COILS 6 REF.
9 TOTAL COILS 8 REF.
10 ONE CLOSE WOUND COILS ON EACH END AND SQUARED WITHIN ±5°.
11 PASSIVATE PER MIL-STD-171, FINISH NO. 5.4.1
12 STRESS RELIEF AFTER FORMING 600° ± 10°F FOR 30 ± 3 MINUTES.
13 MATERIAL: 302 COND. B, COLD FINISH CRE STEEL WIRE QQ-W-423.



QTY REQD		CODE IDENT	PART OR IDENTIFYING NO.	NOMEN DE

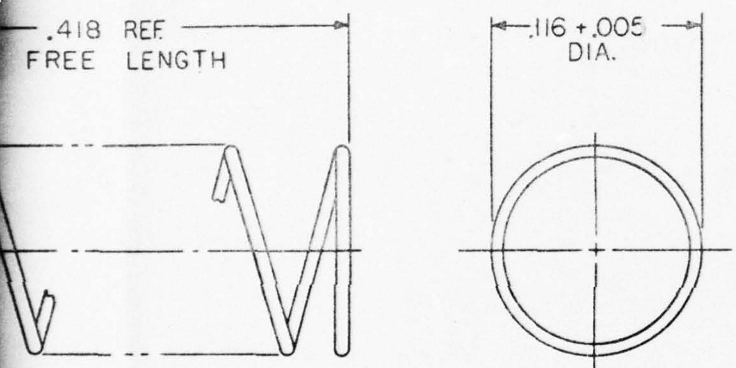
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ± DO NOT SCALE DRAWING		CONTRACT NO. / DRAWN / CHECK / DESIGN
TREATMENT		
FINISH 11		DESIGN ACTIVITY
SIMILAR TO	ACT. WT / CALC WT	CUSTOMER

PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
			7500225	
	QTY REQD PER ASSY		APPLICATION	

9/71 DIETERICH-POST CLEARPRINT 1000

4 3 2

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	MAT'L/SPEC WAS QQ-S-763. NOTE 10. WAS TWO CLOSE WOUND....	10/28/75 OCT 30 1975	HWF
	B	ADDED "REF" TO NOTE 2. ADDED "ONE" TO NOTE 10.	2/24/76 MAR 3 1976	HWF



7500190 B

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPECIFICATION	ITEM NO.

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ±
DO NOT SCALE DRAWING

TREATMENT

FINISH 11

USED ON | SIMILAR TO | ACT. WT | CALC WT

CONTRACT NO.
DRAWN H.W. Fenner
CHECK
DESIGN H. Wolf 3/31/75
DESIGN ACTIVITY H.W. Fenner 7/23/75
CUSTOMER

ADMC AEROJET ORDNANCE AND MANUFACTURING COMPANY

TITLE SPRING, SET BACK, DAMPED

SIZE C | CODE IDENT NO. 13309 | DWG NO. 7500190

SCALE 20/1 | RELEASE DATE OCT 31 1975 | SHEET

1938

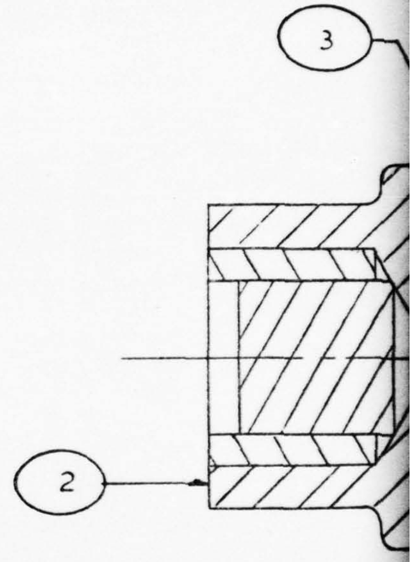
AOC-ORD-88-3035 (REV. 8-73)

5 | 4 | 3

NOTES:

1 SPEC MIL A 2550 APPLY.

2 WHEN INSTALLING D-RING, ITEM 3 EXERCISE CARE IN ASSY TO AVOID CUTTING RING.



1		75
1		76
1		
-1 QTY REQD	CODE IDENT	ID

			7500225	
PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
	QTY REQD PER ASSY		APPLICATION	
DRAWING LEVEL				

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DEC. ANGULAR
.XX ± .03 ± 2°
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DO NOT SCALE DRAWING

MATERIAL

SIMILAR TO	ACT.WT	CALC WT

12/66 DIETERICH-POST CLEARPRINT 1020

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3 | COPY___ 2 | 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

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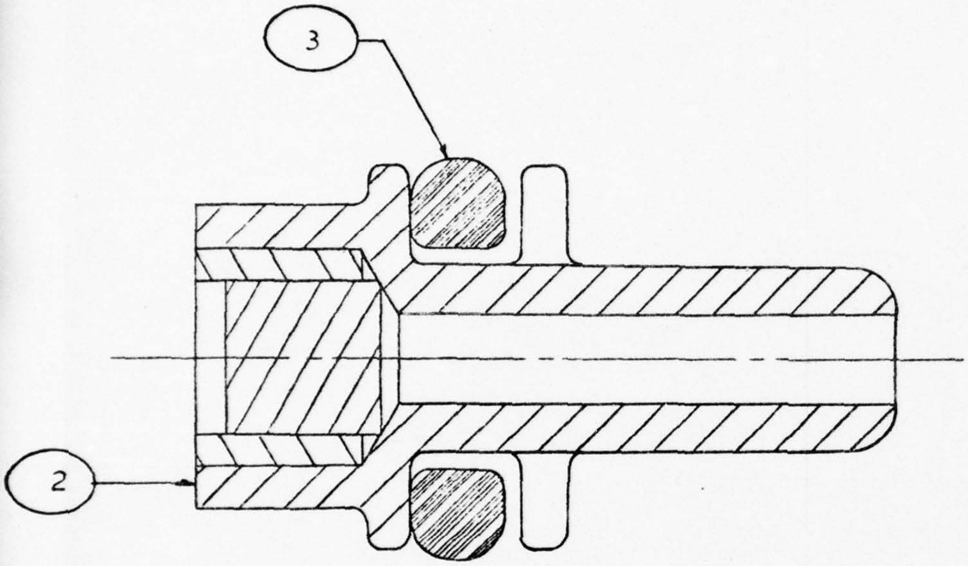

C

B

	1		7500398-1	D-RING	3
	1		7600103-1	PIN, SET-BACK, SUBASSY	2
	1		-1	ASSY	1
-1	QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	ITEM NO.

PARTS LIST

A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCE ON DEC. .XX ± .03 .XXX ± .010 ANGULAR ± 2°
DO NOT SCALE DRAWING

MATERIAL

SIMILAR TO | ACT.WT | CALC WT

D225
ASSY | USED ON
APPLICATION
LEVEL

CONTRACT NO.
DRAWN H. Fukuke | DATE
CHECK
DESIGN | 3/31/76
STRESS/STRUCTURE
MATERIALS
PRODUCTION
DESIGN ACTIVITY APPROVED H. Fukuke
CUSTOMER

AEROJET ORDNANCE AND MANUFACTURING COMPANY
DOWNEY, CALIFORNIA

TITLE PIN, SET-BACK, DAMPED SUBASSEMBLY

DWG SIZE	CODE IDENT NO.	DWG. NO.
B	13309	7600113

SCALE 1938 | RELEASE DATE MAR 31 1976 | SHEET

3 | 2 | 1 06-067-017 (REV 11-63)

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4 3 2

D

NOTES:

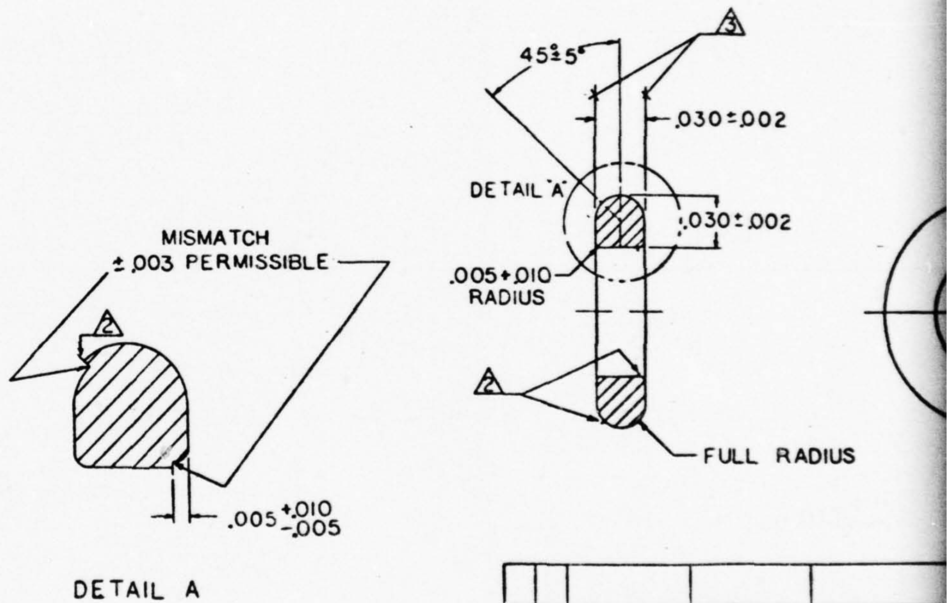
1 SPEC MIL-A-2550 APPLY.

2 .003IN. MAX FLASH PERMISSIBLE.

3 NO FLASHES PERMITTED BEYOND THESE SURFACES.

C

B



A

ZONE LTR

QTY REQD | CODE IDENT | PART OR IDENTIFYING NO. | NOMENCLATURE DESCRIPTION

PART

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS .XX ± .03 .XXX ± .010
ANGULAR ±
DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN

DATE

CHECK

DESIGN

TREATMENT

FINISH

DESIGN ACTIVITY

SIMILAR TO | ACT. WT | CALC WT

CUSTOMER

PART DASH NO. | NEXT | FINAL | QTY REQD PER ASSY | NEXT ASSY | USED ON

APPLICATION

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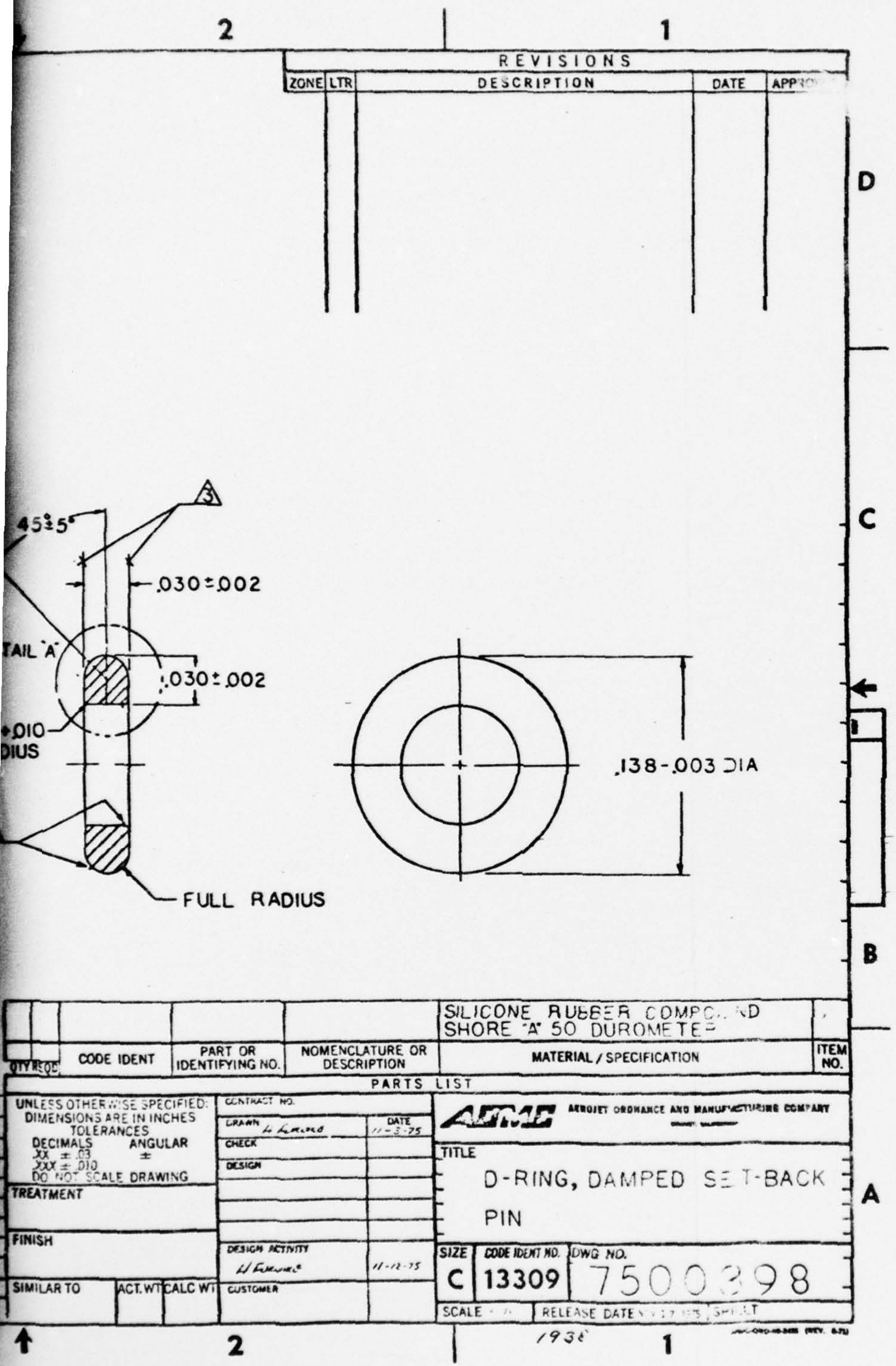
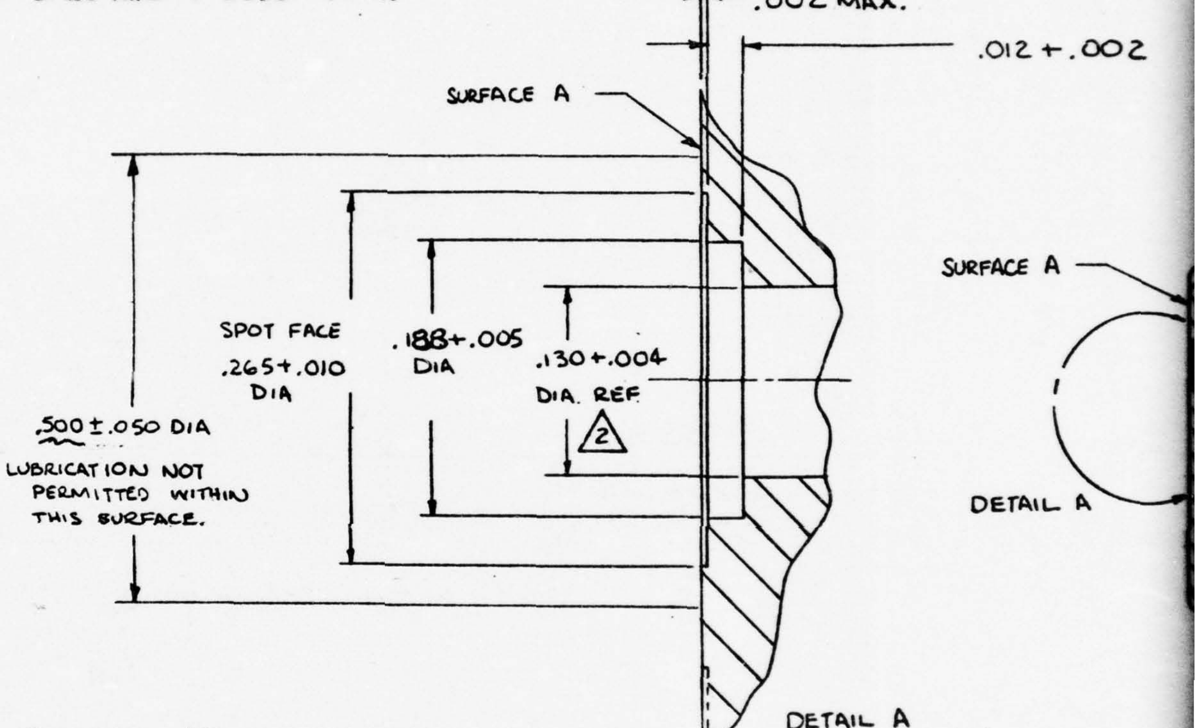

REVISIONS
ZONE LTR DESCRIPTION DATE APPR
D
C
B
A
45° ± 5°
3
.030 ± .002
.030 ± .002
DETAIL "A"
+.010 RADIUS
FULL RADIUS
.138 -.003 DIA
SILICONE RUBBER COMPOUND SHORE "A" 50 DUROMETER
QTY REQD
CODE IDENT
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
MATERIAL / SPECIFICATION
ITEM NO.
PARTS LIST
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS ANGULAR
.XX ± .03 ±
.XXX ± .010
DO NOT SCALE DRAWING
TREATMENT
FINISH
SIMILAR TO
ACT. WT
CALC WT
CONTRACT NO.
DRAWN
DATE 11-3-75
CHECK
DESIGN
DESIGN ACTIVITY
11-12-75
CUSTOMER
AOMC
AEROJET ORDNANCE AND MANUFACTURING COMPANY
TITLE
D-RING, DAMPED SET-BACK PIN
SIZE C
CODE IDENT NO. 13309
DWG NO. 7500398
SCALE
RELEASE DATE
SHEET
1938
2
1

2

5 4 3

NOTES:

1. SPEC MIL-A-2550 APPLY.



2 DIMENSION APPLICABLE BEFORE LUBRICATION IS APPLIED.

3. LUBRICATE USING RECOMMENDED PROCEDURES OF DRAWING 9258680 USING LUBRICANT 9258679.

4 MAKE FROM P/N 9258644.

PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
			7500225	
	QTY REQD PER ASSY		APPLICATION	
DRAWING LEVEL				

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DEC. ANGULAR
.XX ± .03 ± 2°
.XXX ± .010
DO NOT SCALE DRAWING

MATERIAL
4

SIMILAR TO	ACT.WT	CALC WT

12/66 DIETERICH-POST CLEARPRINT 1020

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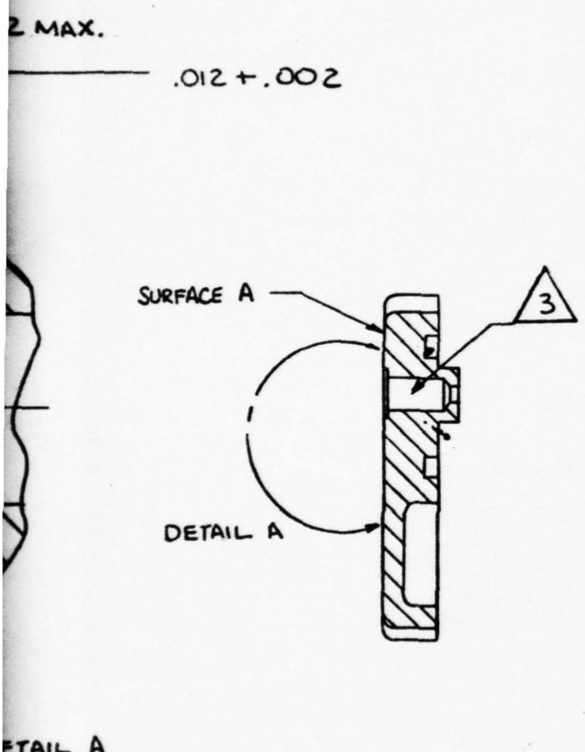
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE N/C DRAWING MAR 31 1976		

D



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B

A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCE ON DEC. .XX ± .03 .XXX ± .010 ANGULAR ± 2° DO NOT SCALE DRAWING	CONTRACT NO.
MATERIAL 4	DRAWN — DATE; CHECK; DESIGN A Wolfe 3/31/76; STRESS/STRUCTURE; MATERIALS; PRODUCTION; DESIGN ACTIVITY APPROVED; CUSTOMER
SIMILAR TO / ACT.WT / CALC WT	

AOMC AEROJET ORDNANCE AND MANUFACTURING COMPANY DOWNEY, CALIFORNIA

TITLE PLATE, BOTTOM, MODIFIED

DWG SIZE	CODE IDENT NO.	DWG. NO.
B	13309	7500367

SCALE	RELEASE DATE	SHEET

.25 | SY USED ON | PLICATION | VEL

3 | 2 1938 | FEB 9 1976 1 06-067-017 (REV 11-63)

2

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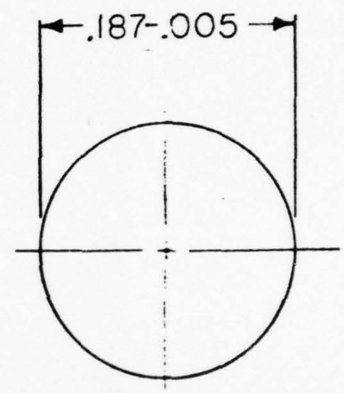
5 4 3

D

NOTES:

1 SPEC MIL-A-2550 APPLY.

2 MATERIAL: STEEL, CRE, SHIM STOCK, COML GRADE, 301 OR 302.



C

B

A

ON	THRU	PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
					7500225	
EFFECTIVE SERIAL NO.			QTY REQD PER ASSY		APPLICATION	
USAGE DATA			DRAWING LEVEL			

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DEC. .XX ± .03 .XXX ± .010 ANGULAR ± 2°
DO NOT SCALE DRAWING

MATERIAL 2

SIMILAR TO	ACT.WT	CALC WT

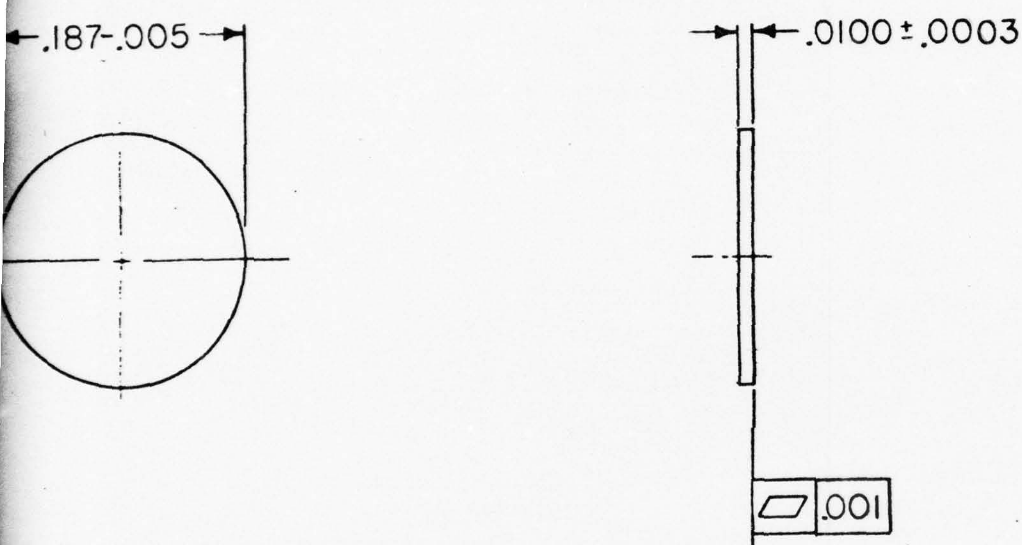
12/66 DIETERICH-POST CLEARPRINT 1020

5 4 3

3 COPY 2 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED FLATNESS DIMENSION.	2/23/76	MAR 31 1976

D



C

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0225	
ASSY	USED ON
APPLICATION	
LEVEL	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DEC. ANGULAR
.XX ± .03 ± 2°
.XXX ± .010
DO NOT SCALE DRAWING

MATERIAL 2

SIMILAR TO	ACT.WT	CALC WT

CONTRACT NO.	DATE
DRAWN H H Furuike	7/21/75
CHECK	
DESIGN H Wolfe	3/31/76
STRESS/ STRUCTURE	
MATERIALS	
PRODUCTION	
DESIGN ACTIVITY APPROVED H H Furuike	7/21/75
CUSTOMER	

AEROJET GENERAL

AEROJET-GENERAL CORPORATION
DOWNEY, CALIFORNIA

TITLE
DISC, CLOSURE

DWG SIZE	CODE IDENT NO.	DWG. NO.
B	13300	7500228

SCALE	RELEASE DATE	SHEET

3 2 1938 AUG 27 1975 1 06-067-017 (REV 11-63)

2

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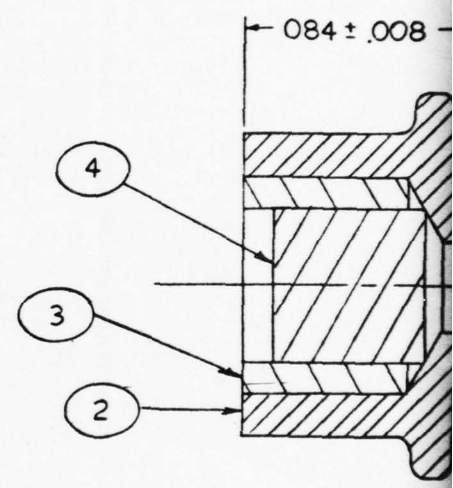
5 | 4 | 3

NOTES:

1 SPEC MIL A 2550 APPLY.

2 AN AXIAL LOAD OF 80 ± 5 LB SHALL BE APPLIED TO THE SLEEVE, ITEM 3. DURING ASSEMBLY.



	1		75
	1		75
	1		75
	1		
QTY REQD	-1	CODE IDENT	IDE

			7600113	
PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
	QTY REQD PER ASSY		APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCE ON DEC. ANGULAR
.XX ± .03 ± 2°
.XXX ± .010
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO	ACT.WT	CALC WT

12/66 DIETERICH-POST C. EARPRINT 1000

2

3 | COPY____ 2 | 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

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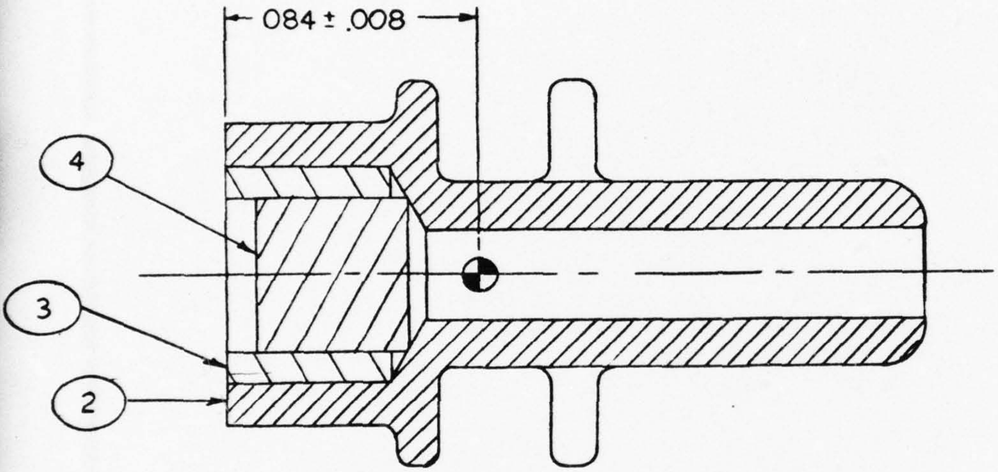


QTY REQD -1	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPECIFICATION	ITEM NO.
1		7500189-1	DISC, SINTERED METAL		4
1		7500227-1	SLEEVE		3
1		7500188-1	PIN, SET-BACK, DAMPED		2
1		-1	ASSY		1

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCE ON DEC. ANGULAR
.XX ± .03 ± 2°
.XXX ± .010
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT.WT | CALC WT

7600113 | NEXT ASSY | USED ON

APPLICATION

CONTRACT NO.

DRAWN W. Furuike | DATE
CHECK
DESIGN W. W[illegible] | [illegible]
STRESS/STRUCTURE
MATERIALS
PRODUCTION
DESIGN ACTIVITY APPROVED W. Furuike | 2/24/76
CUSTOMER

AOMC AEROJET ORDNANCE AND MANUFACTURING COMPANY
DOWNEY, CALIFORNIA

TITLE PIN, SET-BACK SUBASSY

DWG SIZE B | CODE IDENT NO. 13309 | DWG. NO. 7600103

SCALE | RELEASE DATE | SHEET

1938

MAR 31 1976

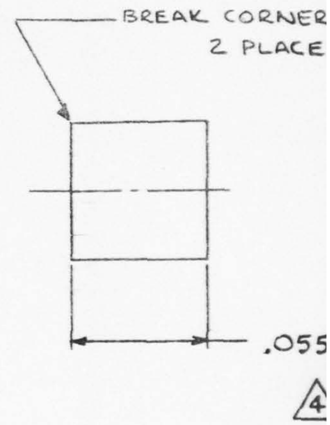
2

5 4 3

NOTES:

1. SPEC MIL-A-2550 APPLY.
2. DENSITY OF PART TO BE .2060±.0115 LB/IN^3
3. SINTERING TEMPERATURE IS 2000 °F FOR 45 MINUTES ± 5 MINUTES IN A HYDROGEN GAS ENVIRONMENT.
4. A PELLET WHICH FAILS TO MEET THIS DIMENSIONAL REQUIREMENT, BUT MEETS THE DENSITY REQUIREMENT, SHALL BE ACCEPTABLE.

△5 316 STAINLESS STEEL - 100 MESH WITHOUT PLASTIC BINDER.



ON	THRU	PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
					7600103	
EFFECTIVE SERIAL NO.			QTY REQD PER ASSY		APPLICATION	
USAGE DATA		DRAWING LEVEL				

UNLESS OTHERWISE SP
DIMENSIONS ARE IN IN
TOLERANCE ON DEC. A
.XX ± .03
.XXX ± .010
DO NOT SCALE DRAW

MATERIAL
△5

SIMILAR TO | ACT.WT

AD-A033 786 AEROJET ORDNANCE AND MFG CO DOWNEY CALIF F/G 19/1
STUDY OF DAMPED SET-BACK PINS FOR S AND A MECHANISMS.(U)
NOV 76 H H FURUIKE DAAA21-75-C-0179
UNCLASSIFIED 1938-00(01)FP NL

2 OF 2
AD
A033786

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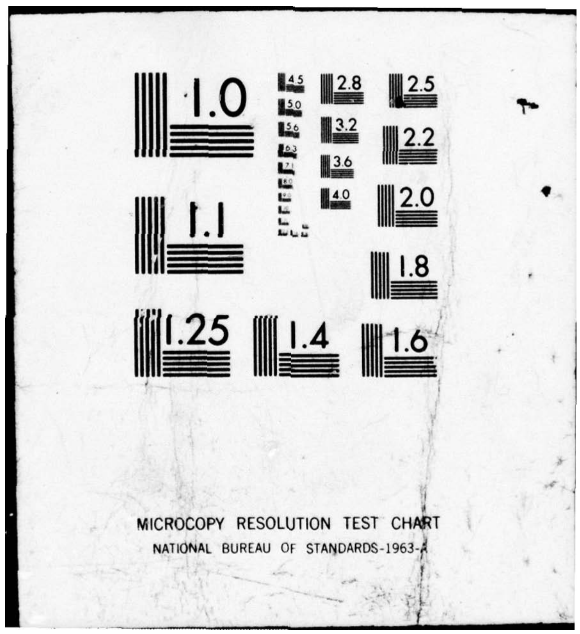
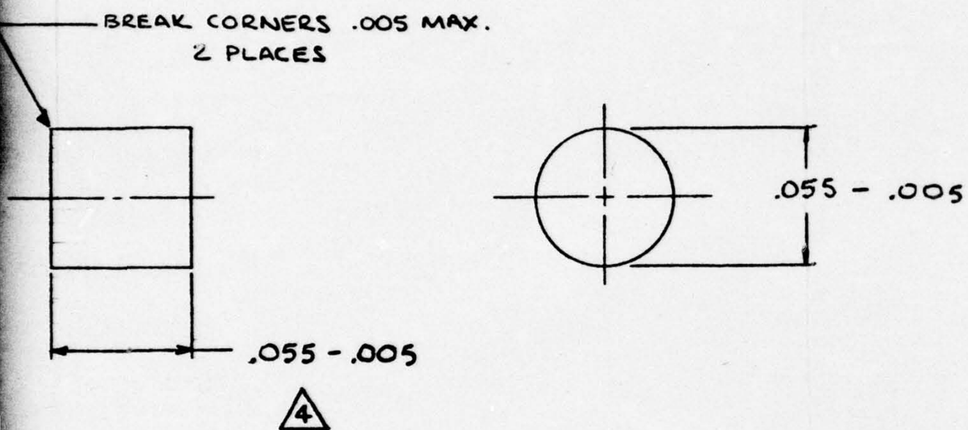
2-77


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

3 COPY____ 2 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED NOTE 4 AND .005 MAX DIM.	2/24/76 MAR 31 1976	JHL

D



C

B

A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCE ON DEC. .XX ± .03 .XXX ± .010 ANGULAR ± 2° DO NOT SCALE DRAWING	CONTRACT NO.	AEROJET-GENERAL CORPORATION DOWNEY, CALIFORNIA
MATERIAL 5	DRAWN H Fukuike DATE 5/21/75; CHECK; DESIGN [signature] 7/31/76; STRESS/STRUCTURE; MATERIALS; PRODUCTION	TITLE DISC, SINTERED METAL
USED ON / CATION	DESIGN ACTIVITY APPROVED H Fukuike 5/21/75	DWG SIZE B; CODE IDENT NO. 13309; DWG. NO. 7500189
SIMILAR TO / ACT.WT / CALC WT	CUSTOMER	SCALE 20/1; RELEASE DATE; SHEET

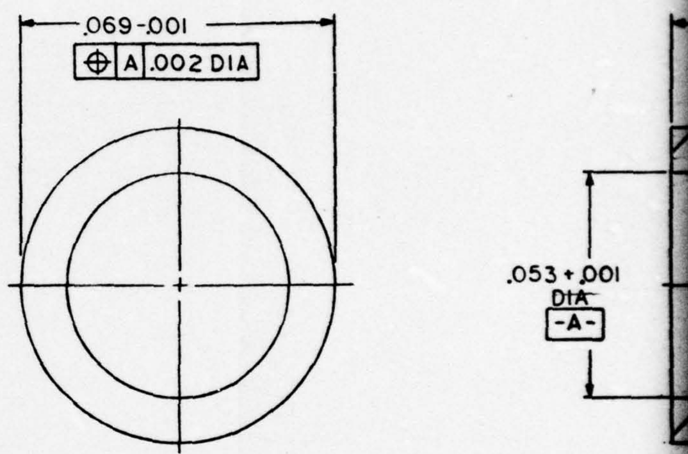
3 2 1938 FEB 9 1976 1 06-067-017 (REV 11-63)

4 3 2

NOTES:

1 SPEC MIL-A-2550 APPLY.

2 MATERIAL: ALUMINUM, 1100, COLD FINISH, WIRE, QQ-A-225/1, TEMPER O



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMEN DES

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS ANGULAR
.XX ± .03 ±
.XXX ± .010
DO NOT SCALE DRAWING

TREATMENT

FINISH

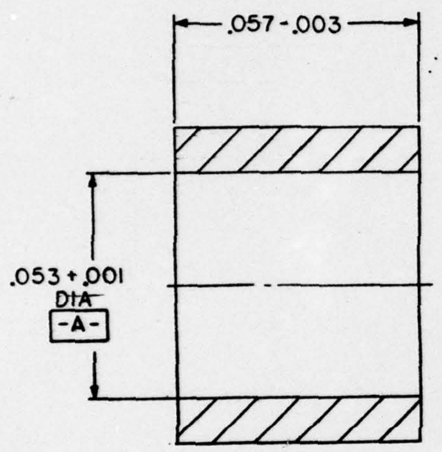
SIMILAR TO | ACT.WT | CALC WT

CONTRACT NO.
DRAWN HH Fur...
CHECK
DESIGN G Wolfe
DESIGN ACTIVITY HH Fur...
CUSTOMER

PART DASH NO.	NEXT QTY REQD	FINAL PER ASSY	NEXT ASSY	USED ON
			76...113	
			APPLICATION	

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED TRUE POSITION TO DATUM A	2/23/76 MAR 3 1 1976	



CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL / SPECIFICATION	ITEM NO.

PARTS LIST

OTHERWISE SPECIFIED:
IONS ARE IN INCHES
TOLERANCES
ALS ANGULAR
.03 ±
.010
T SCALE DRAWING

CONTRACT NO.		
DRAWN	H H Furvine	7/22/75
CHECK		
DESIGN	G Wolfe	3/31/76
DESIGN ACTIVITY	H H Furvine	7/22/75
CUSTOMER		

ACT. WT | CALC WT

AOMC AEROJET ORDNANCE AND MANUFACTURING COMPANY

TITLE

SLEEVE

SIZE	CODE IDENT NO.	DWG NO.
C	13309	7500227

SCALE 50/1 | RELEASE DATE AUG 27 1975 | SHEET

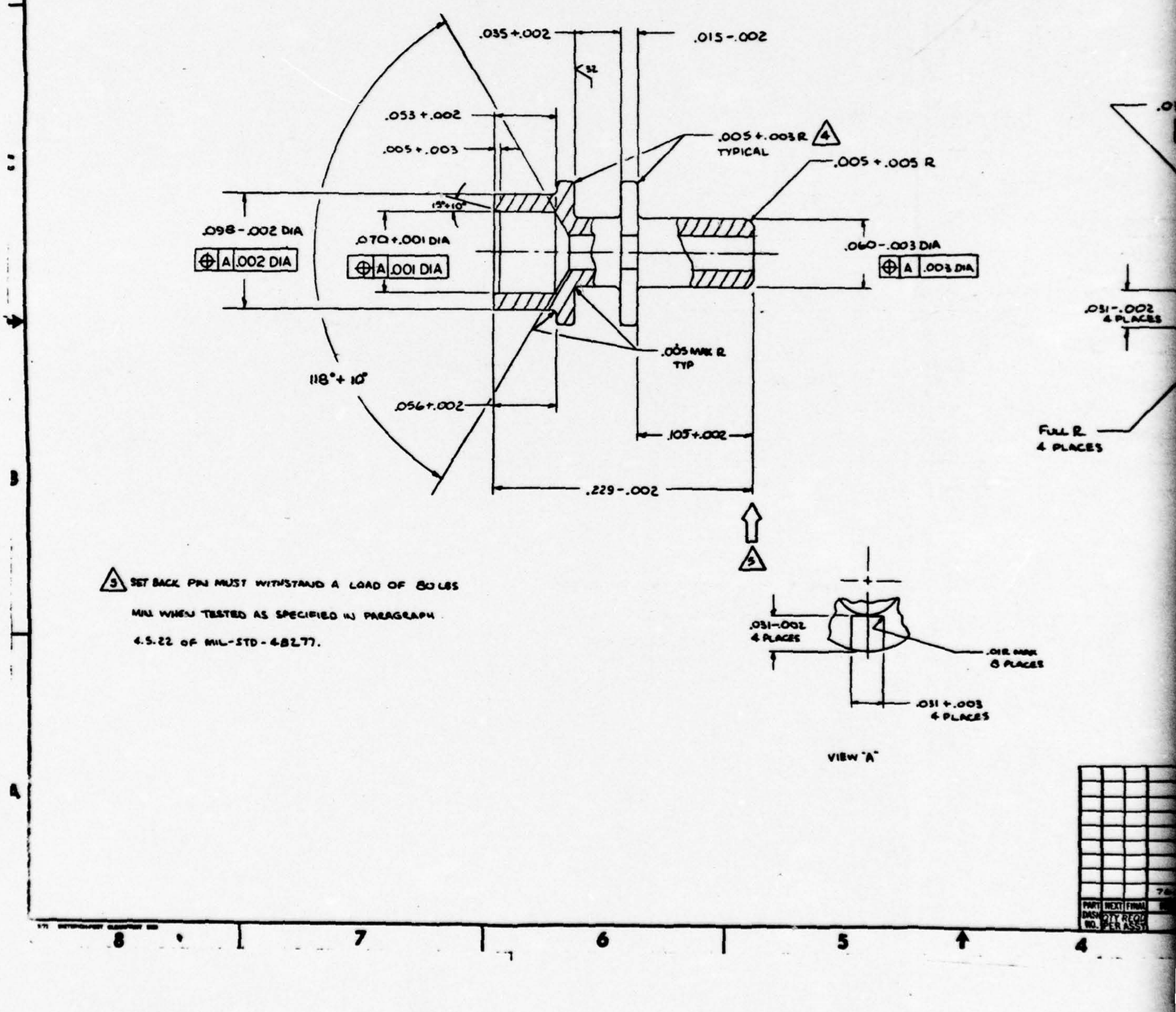
1938

7500227 A

2

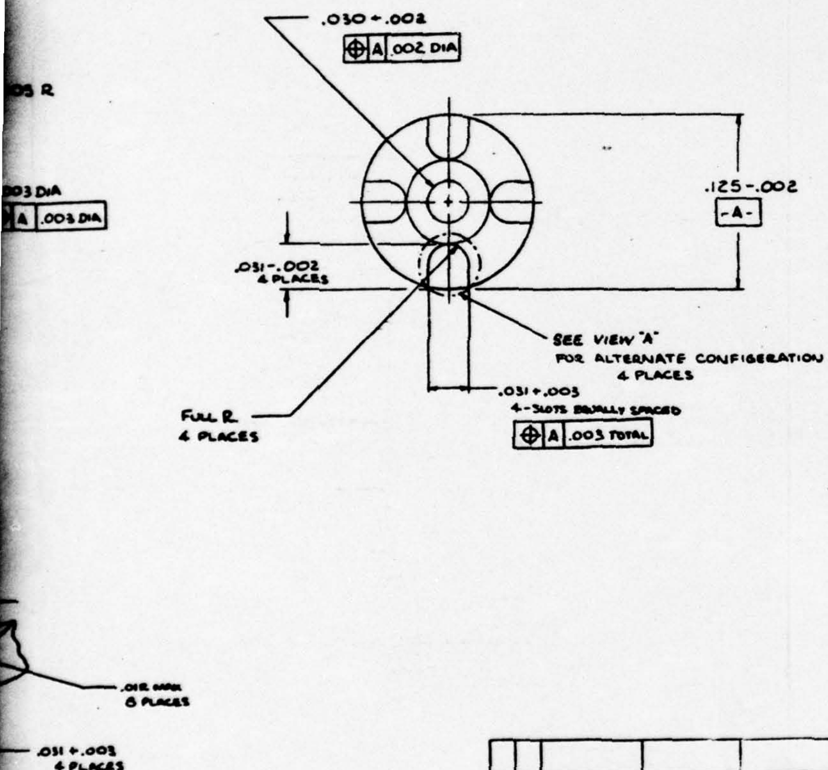
NOTES:

1. SPEC MIL-A-2550 APPLY.
2. SURFACE FINISH TO BE 63/ EXCEPT AS NOTED.
3. PASSIVATE PER MIL-STD-171, FINISH NO 5.4.1
4. FULL RADIUS PERMISSIBLE.



5. SET BACK PIN MUST WITHSTAND A LOAD OF 80 LBS MIN WHEN TESTED AS SPECIFIED IN PARAGRAPH 4.5.22 OF MIL-STD-48277.

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED 15°+10° CHAMFER ADDED .031 – ADDED GENERAL NOTES ... 4.	6/5/75	[illegible]
	B	REVISED	6/16/75	[illegible]
	C	REVISED	6/26/75	[illegible]
	D	ADDED NOTE 5.	2/23/76	[illegible]



7500188

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	ITEM NO.
				STEEL CRE, QQ-S-763 TYPE 303, CONDITION A	

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS XX ± .03, XXX ± .010
ANGULAR ±
DO NOT SCALE DRAWING

TREATMENT

FINISH 3

NEXT ASSY: 7600103

PART DASH NO.	NEXT QTY REQD	FINAL PER ASSY	NEXT ASSY	USED ON
			7600103	

APPLICATION

SIMILAR TO | ACT. WT | CALC WT | CUSTOMER

DESIGN ACTIVITY

AIRMC ... ORDNANCE AND MANUFACTURING COMPANY

TITLE: PIN, SET BACK, DAMPED

SIZE	CODE IDENT NO.	DWG NO.
D	13309	7500188

SCALE | RELEASE DATE | SHEET

1438

2

Appendix C

DESCRIPTION OF MANUFACTURING

C.1 DESCRIPTION OF MANUFACTURING

This appendix documents the fabrication/inspection and assembly of the damped set-back pin system. The method of manufacturing, inspection, and assembly presented here are not to be construed as best methods, but to provide documentation as to how the original damped set-back pin assemblies were fabricated and assembled.

C.2 FABRICATION OF HARDWARE

Damped set-back pin spring (7600190) is manufactured using standard spring coiling machine. Springs inspected for load conformance using a Reicherter spring tester. Spring was guided with a 0.062-in.-diameter pin to prevent spring buckling. Spring tester sold by the Callson Co. of Long Island, New York.

Damped set-back pin O-ring (7600398) is manufactured using single cavity mold with parting lines shown on Page 81. Flashes are removed by freezing O-ring and buffing off flashings. O-rings were inspected using a comparitor for diameter, flashes, and mismatch.

Modified bottom plate (7500367) is modified by removing the protrusion (boss) on the aft end, which originally housed a set-back pin (undamped). A spot-face depth of 0.002 in. maximum is permitted to ensure that the boss is removed. Other modifications include a 0.188-in.-diameter by 0.012-in.-deep counterbore and an addition of Emralon 330 lubricant. Counterbore is made using standard open set-up machining practice. Application of lubrication in the 0.130 + 0.004-in.-diameter cavity is done by the spray method with masking around the counterbore and 0.500-in. diameter surface as shown on the drawing. Masking is necessary to ensure that sealing can be accomplished using MIL-A-82484 sealant in the final assembly of the damped set-back pin assembly. (Sealant will not adhere to the Emralon 330 lubricant.) Inspection of the machined part is performed using a standard measuring instrument. Lubrication application is certified by the lubricant vendor.

Closure disc (7600228) is manufactured using a standard 3/16-in.-diameter punch and is inspected by SMI.

Sintered metal disc (7500189) is manufactured using a constant-volume technique. Notes on the drawing describe material, powdered metal size, and curing temperature. Inspection consists of size, weight, and flow rate measurements. Size and weight measurements determine density of the sintered metal disc. Flow rate is measured using the water tower shown in Figure C-1

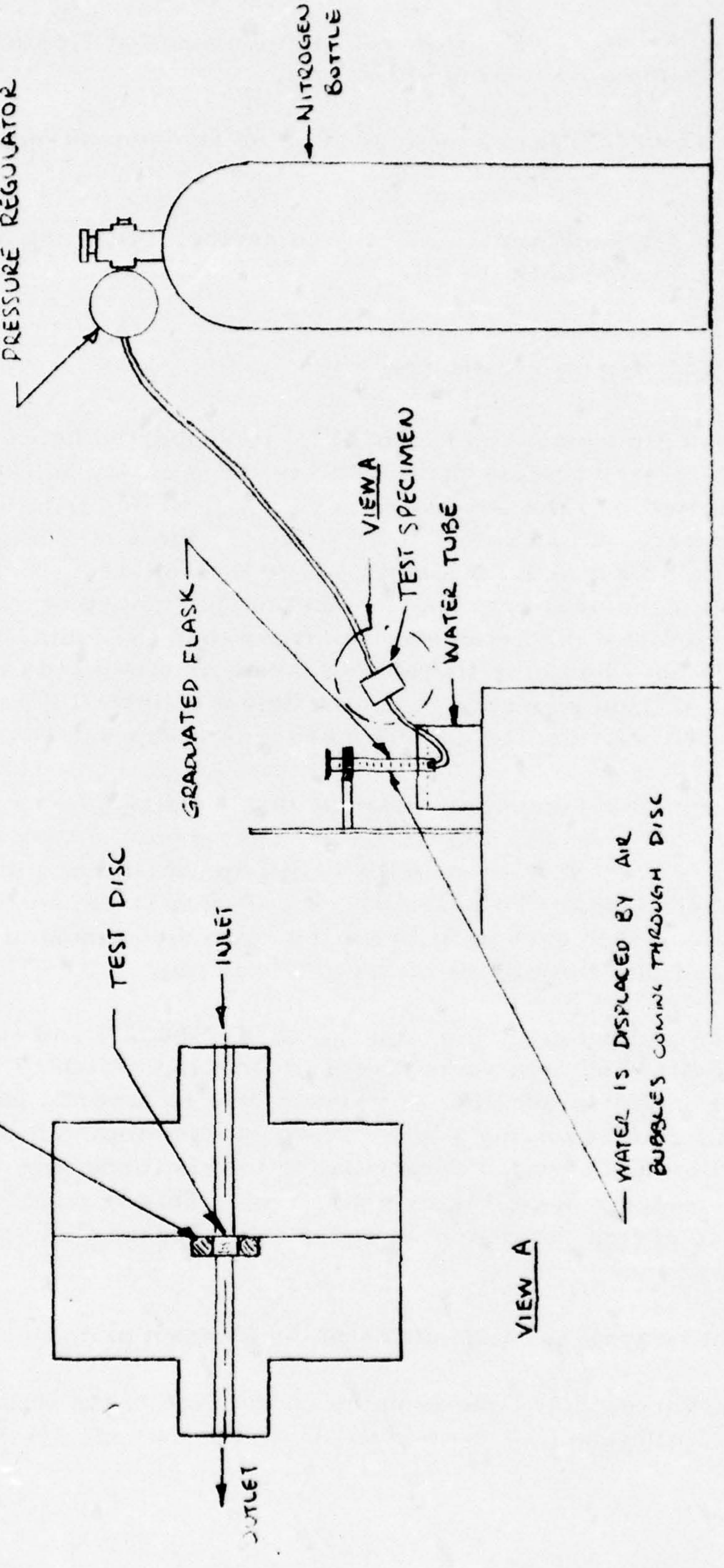


Figure C-1. Flow Rate Measuring Device.

and a stop watch. The flow rate is measured at 7 psig and is performed several times for average flow rate.

Sleeve (7500227) is manufactured using an open set-up and is inspected using SMI.

Damped set-back pin (7500188) is manufactured using an open set-up, and inspected using SMI.

C.3 ASSEMBLY OF HARDWARE

Set-back pin subassembly (7600103) is supported between the two flanges using a 1/32-in. -thick steel sheet with the large cavity hole facing up. The sleeve is installed into the set-back pin cavity first and then the sintered metal disc is inserted. A punch that is relieved for the sintered metal disc is used to apply an 80 ± 5 lb axial load to swage the soft 1100-0 aluminum sleeve to provide a mechanical seal 360° around the periphery of the porous disc. If the sintered metal disc diameter is larger than the inside diameter of the sleeve, a 0.045-in. -diameter flat bottom punch may be used to hand press the disc into place. If hand pressure is not sufficient to install the disc, the sleeve/sintered metal disc is rejected and replaced with a new set.

The damped set-back pin subassembly (7600113) O-ring is installed using the simple tool shown in Figure C-2. The assembly tool (a truncated cone in shape) is made to slip over the 0.060-in. -diameter pin and straddle the upper or vented flange. To assembly, the O-ring is slipped onto the assembly tool and slowly stretched as it is moved down the truncated section until the O-ring is placed into the groove of the set-back pin.

The damped set-back pin subassembly (7500225) and spring are installed into the modified back plate as shown in Drawing, 7500225. The closure disc is placed on the spring and the closure disc is lowered into place and the bottom plate is crimped using a 360° interrupted crimping method (crimped to a depth of 0.005 + 0.010 in). The crimping tool is made with a spring loaded plunger in the center axis of the crimping tool. This is done to hold the closure disc in place during the crimping operation. Figure C-3 shows the crimping tool head section.

Sealant is applied on closure disc and bottom plate to obtain an air tight seal.

Inspection of delay time is noted on the face of the drawing. A special fixture shown in Figure C-4 is used to obtain the damped set-back pin delay time.

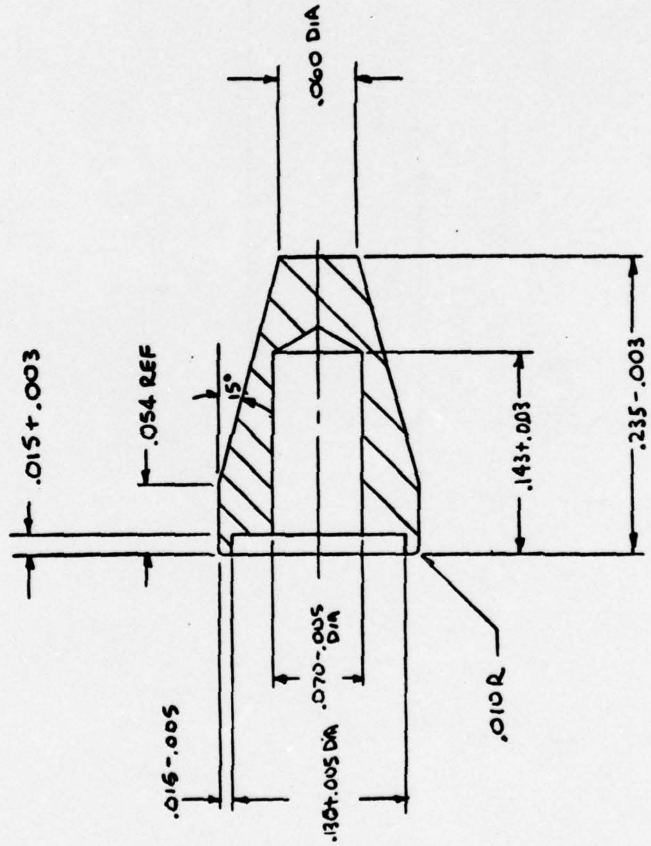


Figure C-2. O-Ring Assembly Aid.

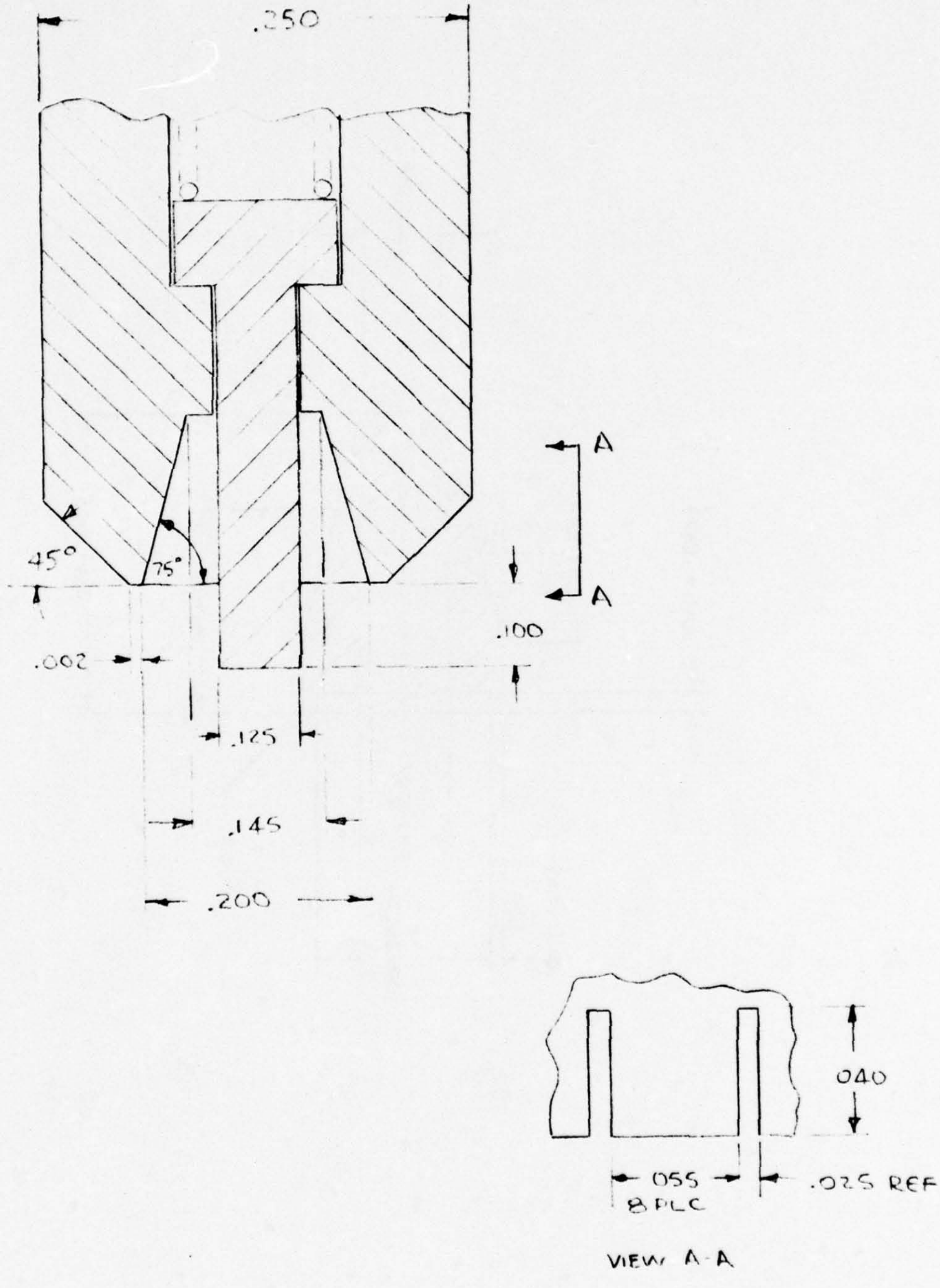


Figure C-3. Crimping Tool Head.

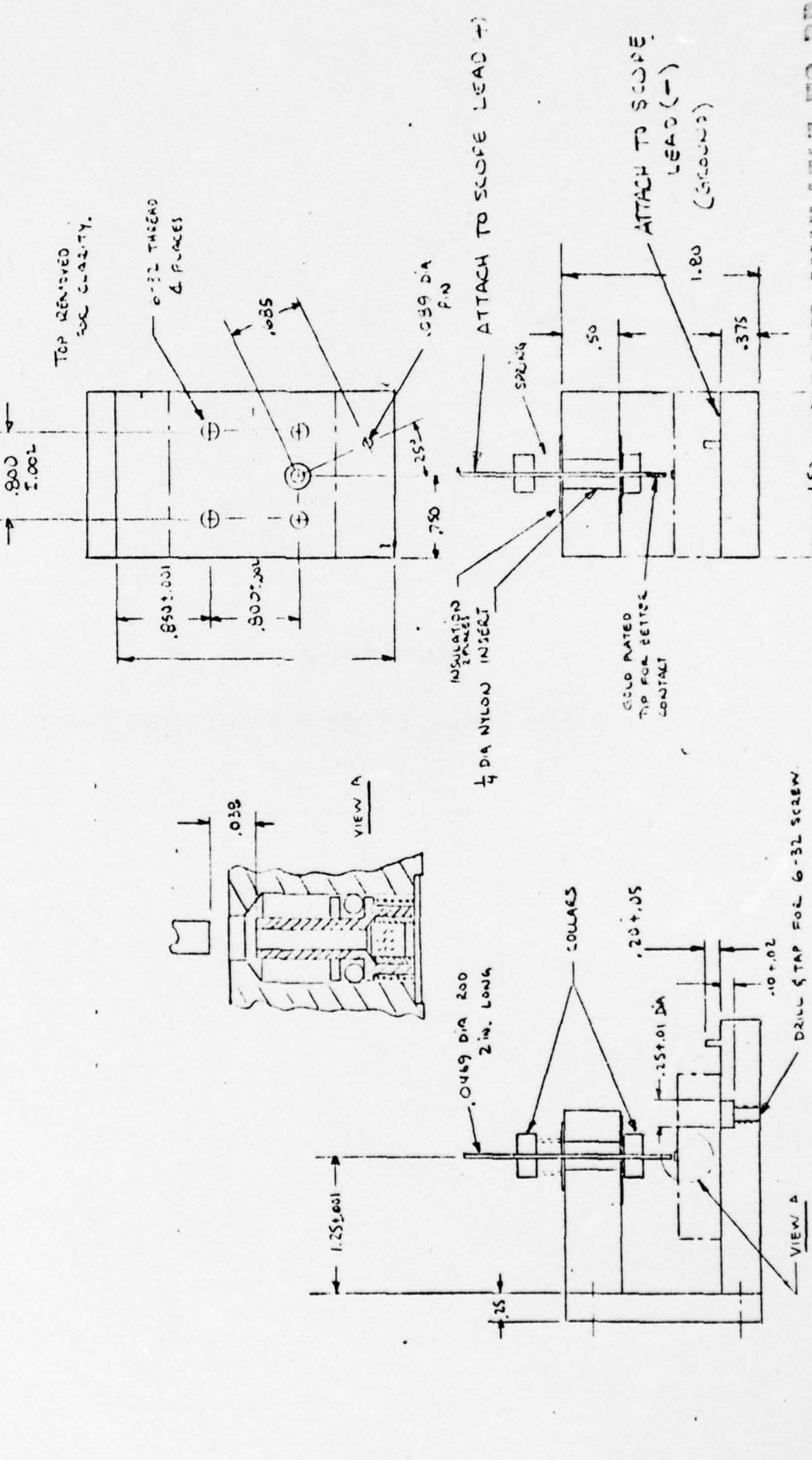


Figure C-4. Special Delay Time Fixture.

Appendix D

COMPATIBILITY AND FRICTION TESTING

D.1 COMPATIBILITY TEST

Lubrication is used to minimize the O-ring friction drap and provide for a uniform friction force throughout the temperature extremes which the S&A device might be exposed to. The best suited lubrication was selected based on campatibility and friction testing.

To determine the compatibility of the silicone O-ring and lubrication an extended soak test was conducted. Various lubrications were used on silicone compound O-rings. Lubrications used in the tests included:

a. Braycote 640 AC (Kratox 240 AC)

b. Braycote 668

c. Dow Corning 55M (Silicone Grease)

d. Dow Corning 33 (Silicone Grease)

e. Vydax 525 (Teflon Film)

f. Emralon 313 (Teflon Bonded)

g. Emralon 330 (Teflon Bonded)

Compatibility test results are shown in Table D-1.

Test results showed that both Braycote lubrications, 668 and 640 AC, did not affect the growth of the silicone O-ring diameter after soaking for 192 hours. The Braycote 640 AC lubricant was tested on S469 and S613 O-ring compound with shore hardness of 40 and 60 "A" durometer, respectively. Braycote 668 lubricant was tested on S469 O-ring compound only.

When the silicone O-ring was soaked in the silicone lubricant, which meets MIL-G-4343 specifications, an appreciable growth was observed. Dow Corning 55M caused S469 O-ring compound a diametral growth of approximately 11% after 120 hours of soaking. Additional 48 hours of soaking caused no further increase in diametral growth. When a like compound O-ring was immersed in Dow Corning 33, a diametral growth of approximately 12% was observed after 120 hours of soaking.

Table D-1. Compatibility Test.

O-Ring Type	Original Size	O-Ring Size After				Type Grease	Percent Growth				Remarks
		2 Hr.	120 Hr.	168 Hr.	192 Hr.		2 Hr.	120 Hr.	168 Hr.	192 Hr.	
S469	.1769		.1768		.1764	Braycote 640AC		0		0	No Appreciable Growth
S469	.1774		.1778		.1779	"		0		0	"
S469	.1775		.1756		.1755	"		0		0	"
S469	.1758		.1762		.1760	"		0		0	"
S613	.1766		.1764		.1770	"		0		0	"
S613	.1763		.1762		.1764	"		0		0	"
S469	.1778		.1776		.1775	Braycote 668		0		0	"
S469	.1763		.1761		.1763	"		0		0	"
S469	.1783		.1780		.1782	"		0		0	"
S469	.1766		.1766		.1760	"		0		0	"
S469	.1756		.1950	.1949		D.C. 55M		11.0	11.0		Grease Conforms to MIL-G-4343
S469	.1770		.1956	.1959		"		10.5	10.7		"
S469	.1760		.1950	.1954		"		10.8	11.0		"
S469	.1763		.1950	.1958		"		10.6	11.1		"
S613	.1760		.1882	.1883		D.C. 33		7.0	7.0		"
S613	.1763		.1888	.1886		"		7.0	7.0		"
S613	.1780		.1906	.1908		"		7.0	7.2		"
S613	.1765		.1895	.1890		"		7.4	7.1		"
S469	.1780		.1996	.1997		"		12.1	12.2		"
S469	.1761		.1993	.1990		"		13.2	13.0		"
S469	.1763		.1970	.1975		"		11.7	12.0		"
S469	.1759		.1979	.1980		"		12.5	12.6		"
S469	.1773	.2290				Vydax 525	29.2				Swelling takes place within 2 hours but as FREON TF solvent evaporates O-ring goes back to original size. White residue is left.
S469	.1764	.2646				"	50.0				
S613	.1766	.2244				"	27.1				"
S613	.1764	.2146				"	27.7				"

Emralon lubricant was found to be compatible with Silicone O-ring. Emralon lubricant is bonded to the metal part rather than to the O-ring.

An O-ring made from S613 compound was soaked in Dow Corning 33 to observe the diametral growth. It's growth was recorded at approximately 7% after 120 hours and there was no further growth after an additional 48 hours.

Vydax 525 lubricant, a dispersion of a short-chain telomer of tetrafluoethylene in FREON TF solvent, affected the O-ring growth which was dependent on the amount of lubricant the O-ring was imersed in. One O-ring was observed to have grown 50% while another 21%. This growth, however, is only a temporary one; that is, after the FREON solvent evaporates the O-ring slowly returns to its original size.

Another observation should be noted here. After the evaporation of FREON solvent from this O-ring took place a white crusty film (lubricant) was present on the O-ring surface, which came off very easily. Therefore, the O-ring itself should not be immersed in the Vydax solution but only the bottom plate should be lubricated to minimize the contamination of the air flow restrictor. That is, if the white crusty film flakes become detached from the O-ring the Vydax residue could invariably clog or plug the sintered metal disc and cause an excessive delay or lock the set-back pin.

Emralon 312 and 330 are bonded Teflon lubricants. Since Teflon is inert to silicone rubber these lubricants are compatible. The advantage of the use of Emralon lubricant is that the air restrictor cannot be contaminated by the lubricant because of the bonded characteristic of this lubricant to the metal part.

Emralon 330 is currently used on the escapement portion of the S&A that is being considered for modification. This lubrication is a resin-bonded PTFE lubricant. Only an extremely thin coating of Emralon 330 is necessary to achieve maximum lubrication, which can be applied by spraying or dipping.

D-2. O-RING FRICTION FORCE MEASUREMENT

O-ring friction test was conducted using a test fixture to measure break-up and sliding friction forces. A force gage with a follower needle which measures force in grams is mounted on a sliding saddle which is guided by a rod. This rod prevents the tilting or the lateral movement of the saddle therefore giving a smooth longitudinal movement. The saddle along eith the force gage is moved by torqueing or turning of the tension screw located at one end of the test fixture. This motion produces a force on the test specimen which is connected to the force gage arm via a small hook. The screw is turned slowly until movement of the O-ring takes place (a visual observation). This force

is noted by a follower needle and recorded as the break-out force. Upon stopping the tension screw, when O-ring break-out is observed, the force gage indicator needle slowly decreases (follower needle is now stationary at maximum force) until an equilibrium force is obtained with the test specimen. This force is noted and recorded as the sliding friction force.

Different O-ring and sleeve sizes were tested to establish friction force with respect to O-ring diametrical squeeze. Two types of lubricants were found to be suited for the damped set-back pin system after testing Braycote 640 AC, Braycote 668, Vydax 525, Emralon 330, and Emralon 312 lubricants. The two lubricants which were found to be comparable in friction force are Braycote 640 AC and Emralon 330.

Test results using Braycote 640 AC (Table D-2) showed that maximum break-out frictional force of 26 gm was obtained at -40°F with a diametrical squeeze of approximately 0.008 in. The sliding friction force was found to be approximately 7 gm. Emralon 330 friction force (See Table D-3) was found to be as follows: Break-out friction at 23 gm and sliding friction at approximately 10 gm, all at -40°F.

Emralon 330 was selected on three factors: (1) Controlled lubrication film, (2) Lubrication will not contaminate the porous material used for the delaying action of the pin, and (3) Elimination of lubricant migration during varying temperature changes during storage.

Table D-2. Friction Test.

TEMPERATURE: Ambient
O-RING TYPE/SIZE: S5010/.138-.003

SLEEVE TYPE: Aluminum
LUBRICANT: Braycote 640 AC

O-Ring Dia. In.	Sleeve Dia. In.	Diametrical Squeeze, in.	Break-Out Force, gm.	Sliding Force, gm.	Remarks
.1364	.1302	.0062	15	-	
			13	5	
			14	5	
			12	5	
			14	5	
			13.6 avg	5 avg	
.1377	.1302	.0075	15	5	
			12	5	
			14	5	
			17	5	
			17	5	
			15.0 avg	5 avg	
.1355	.1302	.0053	8	5	
			9	5	
			11	5	
			11	5	
			8	5	
			9.4 avg	5 avg	
.1377	.1337	.0040	8	5	
			7	5	
			8	5	
			8	5	
			8	5	
			7.8 avg	5 avg	

Table D-2. Friction Test. (Continued)

TEMPERATURE: -40°F
O-RING TYPE/SIZE: S5010/.138 dia

SLEEVE TYPE: Aluminum
LUBRICANT: Braycote 640 AC

O-Ring Dia. In.	Sleeve Dia. In.	Diametrical Squeeze, in.	Break-Out Force, gm.	Sliding Force, gm.	Remarks
.1355	.1337	.0018	13	5	
			15	5	
			13	5	
			17	5	
			14.5avg	5avg	
.1355	.1302	.0053	18	8	
			21	5	
			15	5	
			19	5	
			18.25avg	5.75avg	
.1377	.1302	.0075	26	5	
			23	5	
			23	5	
			24avg	5avg	
.1377	.1337	.0040	16	5	
			15	5	
			16	5	
			15.67avg	5avg	

Table D-2. Friction Test. (Continued)

TEMPERATURE: **145°F** SLEEVE TYPE: **Aluminum**
O-RING TYPE/SIZE: **S5010/.138 dia** LUBRICANT: **Braycote 640 AC**

O-Ring Dia. In.	Sleeve Dia. In.	Diametrical Squeeze, in.	Break-Out Force, gm.	Sliding Force, gm.	Remarks
.1355	.1302	.0053	8	5	
			10	8	
			13	10	
			13	8	
			11avg	7.75avg	
.1355	.1337	.0018	11	5	
			11	5	
			10	8	
			10.67avg	6avg	
.1377	.1337	.0040	11	5	
			10	5	
			11	8	
			10.67avg	6avg	
.1377	.1302	.0075	11	10	
			12	11	
			14	5	
			14	11	
			15	5	
			13.2avg	8.4avg	

Table D-3. Friction Test.

TEMPERATURE: Noted
O-RING TYPE/SIZE: 7500147

SLEEVE TYPE: Aluminum
LUBRICANT: Emralon 330

O-Ring Dia. In.	Sleeve Dia. In.	Diametrical Squeeze, in.	Break-Out Force, gm.		Sliding Force, gm.	Remarks
.137	.133	.004	15	16.5	≈10	
.137	.133	.004	18			
.138	.133	.005	14			70°F
.138	.133	.005	16	14.0	≈10	
.138	.133	.005	12			
.137	.133	.004	13/14	14.0	≈10	
.137		.004	15			
.138		.005	>10			+145°F
.138		.005	16	14.0	≈10	
.138	.133	.005	12			
.137	.133	.004	23	21.5	≈10	
.137		.004	20			
.138		.005	18			-40°F
.138		.005	20	19.3	≈10	
.138	.133	.005	20			

Appendix E

LONG TUBE ORIFICE DESIGN

E.1 PRESSURE DROP - AIR - CIRCULAR TUBE

Incompressible Laminar Flow*

$$\Delta P = \frac{8\mu \ell \bar{v}}{r^2} \tag{1}$$

where

μ_{Air} = 0.0373 x 10^{-5} lb-sec/ft^2

ℓ = tube length, in.

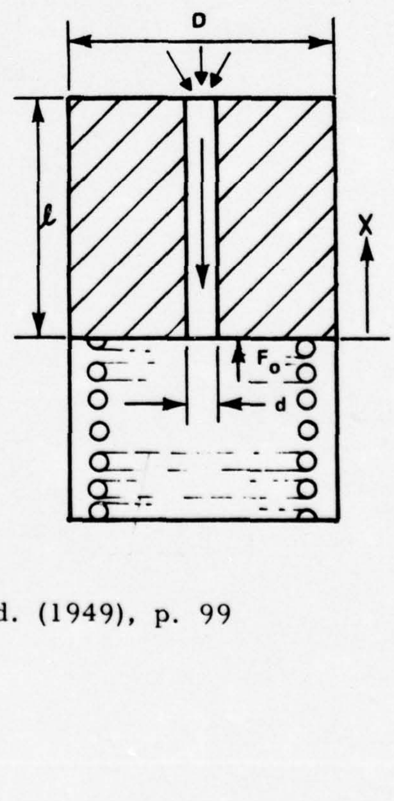
r = tube radius, in.

$\bar{v}$ = average flow velocity, in./sec

ΔP = pressure drop, lb/in.^{2}

$$\Delta P = \frac{(8)(0.0373)(\ell)(\bar{v})}{(10^5)(r^2)(144)} = \frac{(8)(0.0373)\ell\bar{v}}{(144)(10^5)r^2} = \frac{2.07222}{10^8}\frac{\ell\bar{v}}{r^2}$$

$$\Delta P = \left(\frac{2.07222}{10^8}\right)\frac{\ell\bar{v}}{r^2} \qquad r = \frac{d}{2} \tag{2}$$



$$\Delta P = \left(\frac{8.28888}{10^8}\right)\frac{\ell\bar{v}}{d^2} \tag{2a}$$

$$F = \Delta P A_p = \Delta P \frac{\pi}{4} D^2 \tag{3}$$

$$F = \frac{(8.28888)}{10^8}\frac{\pi}{4}\frac{D^2\ell\bar{v}}{d^2}$$

$$= \left(\frac{6.51007}{10^8}\right)\frac{D^2\ell\bar{v}}{d^2} \tag{3a}$$

*From Fluid Mechanics, Prentice Hall, 2nd Ed. (1949), p. 99

$$F = \frac{6.51007}{10^8} \frac{D^2 \ell \bar{v}}{d^2}$$

$$D = 0.134 \text{ in.}$$

$$F = \left(\frac{0.11689}{10^8}\right) \frac{\ell \bar{v}}{d^2} \tag{3b}$$

Let

$$V = \text{piston velocity, in./sec}$$

Then:

$$A_H \bar{v} = A_p V$$

$$\bar{v} = \frac{A_p V}{A_H} \quad \frac{D^2 V}{d^2}$$

From Equation 3b,

$$F = \left(\frac{0.11689}{10^8}\right) \frac{\ell}{d^2} \quad \frac{D^2 V}{d^2} \qquad D = 0.134 \text{ in.}$$

$$F = \left(\frac{2.098877}{10 \text{ in.}}\right) \frac{V}{d^4} \tag{4}$$

$$V = \frac{dx}{dt} \tag{5}$$

$$F = \alpha \frac{dx}{dt} \text{ where } \alpha = \left(\frac{2.098877}{10 \text{ in.}}\right) \frac{\ell}{d^4} \tag{6}$$

$$dt = \alpha \frac{dx}{F} \tag{6a}$$

$$F = F_o - kx \tag{7}$$

$$dt = \alpha \frac{dx}{F_o - kx} = \frac{-k\alpha}{-k} \frac{dx}{(F_o - kx)} \tag{8}$$

$$t = \frac{\alpha}{-k} \ell n \, (F_o - kx) \Big|_o^x = \frac{\alpha}{k} \ell n \left(\frac{F_o}{F_o - kx} \right) \tag{8a}$$

$$t = \frac{\alpha}{k} \ell n \left(\frac{F_o}{F_o - kx} \right) = \left(\frac{2.098877}{10 \text{ in.}} \right) \frac{\ell}{kd4} \ell n \left(\frac{F_o}{F_o - kx} \right) \tag{9}$$

$$t = \left(\frac{2.098877}{10 \text{ in.}} \right) \frac{\ell}{kd4} \ell n \frac{F_o}{F_o - kx}$$

$x = 0.091 \qquad \ell = 0.170$

k	F_o	kx	F_o -kx	$\ell n \frac{F_o}{F_o - kx}$	$\frac{2.098877}{k10 \text{ in.}} \ell n \frac{F_o}{F_o - kx}$	td^4
0.033	0.0119	0.003003	0.008897	0.29082	1.84968×10^{-10}	0.31444×10^{-10}
0.167	0.1099	0.015197	0.094703	0.148825	1.87045×10^{-11}	0.31798×10^{-11}
0.379	0.0887	0.034489	0.054211	0.492376	2.72674×10^{-11}	0.46355×10^{-11}
0.830	0.1096	0.07553	0.03407	1.16842	2.95466×10^{-11}	0.50229×10^{-11}

d	d^4	t (sec)				
		k				
		0.033	0.167		0.379	0.830
0.002	16×10^{-12}	1.965	0.1987	Yes	0.2897	0.3139
0.004	2.56×10^{-10}	0.1228	0.01242	No	0.0181	0.0196
0.006	1.296×10^{-9}	0.0242	0.002453			
0.008	4.096×10^{-9}	0.00767	0.000776			

The data above show that to get $\gtrsim$100 msec delay, the hole through the piston will have to be in the neighborhood of 0.002 to 0.004 in. in diameter, which is too small to be practical.

Appendix F

COMPUTER SIMULATION PROGRAMS

This Appendix describes the computer simulation programs of the dynamic response of the Damped Set-Back Pin assembly. Two computer programs are used to describe the motion of the pin: (1) Continuous system modeling program (CSMP), Figure F-1, to describe the pin retracting mode during internal ballistic environment and (2) Fortran IV to describe the return stroke of the pin after the projectile leaves the gun tube.

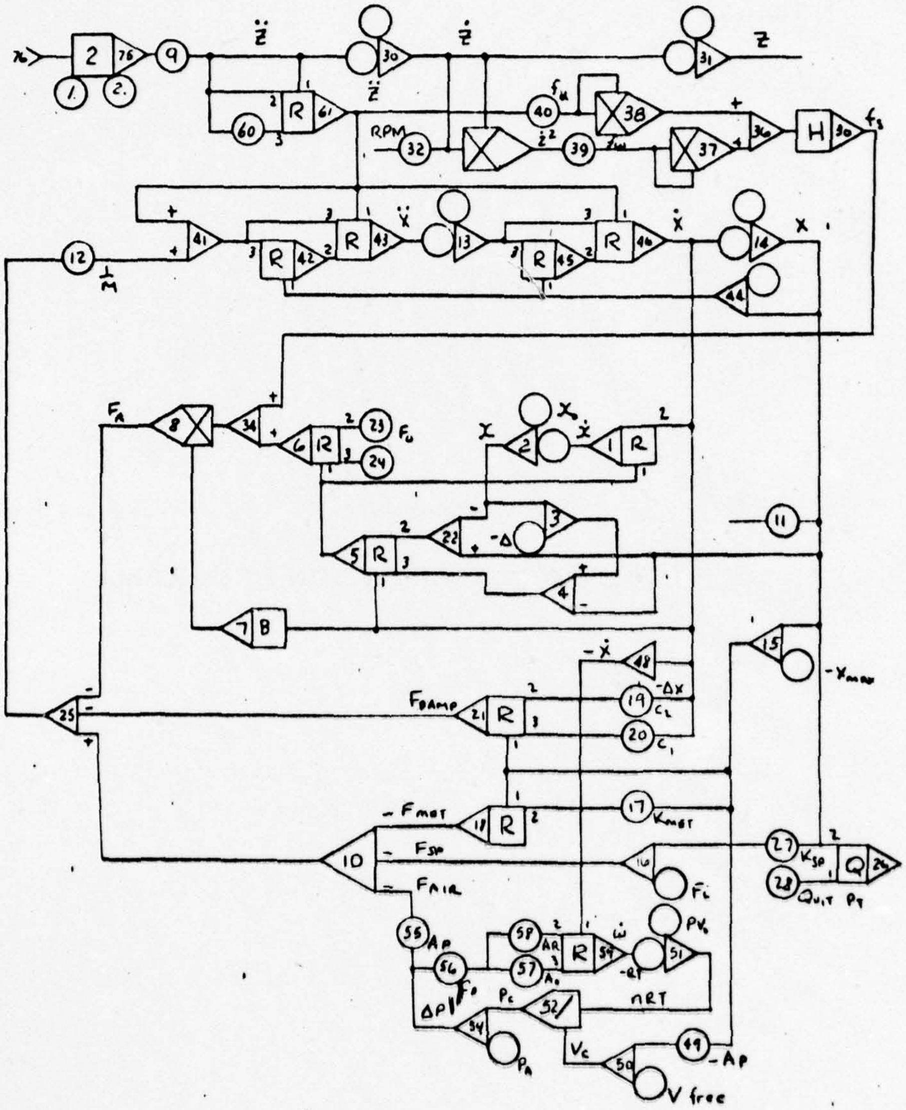


Figure F-1. CSMP.

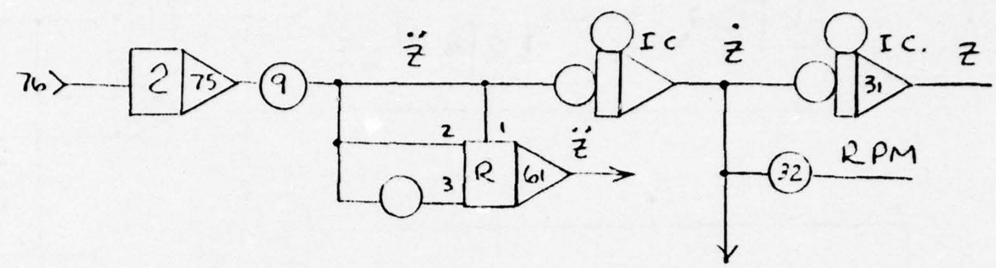


Figure F-2. Projectile Motion.

Equations Simulated:

$A = f(t)$ or $P = f(t)$ and $F = Pa$

$$A = \frac{F}{M} = \ddot{Z} = \frac{d^2z}{dt^2}$$

Notation:

A = Acceleration	P = Pressure
t = Time	a = Area
F = Force	M = Mass

Operation: (Figure F-2)

Block 75 has its output as a function of input. Since a function of time is desired, the time signal available from Block 76 is used. If $A = f(t)$ is available it may be used directly. Usually $P = f(t)$ only is available, so Block 9 gain is used to derive acceleration from the projectile area and mass, and the energy ratio of the gases. This is successively integrated to obtain $\dot{Z}$, velocity, and Z, position, from Blocks 30 and 31. For convenience, RPM is also computed, in Block 32.

Acceleration takes place while the projectile is within the gun so spin and longitudinal motion are tied together by the rifling of the gun barrel. After the projectile leaves the gun it is decelerated by aerodynamic drag and the spin deceleration and longitudinal deceleration are no longer the same. Block 60, then, is the constant of proportionality between the two drag factors. The relay, Block 61, has its output equal to Input 2 when Input $1 \geq 0$ and output equal to Input 3 when Input $1 < 0$, so it is triggered when the acceleration from Block 9 becomes negative.

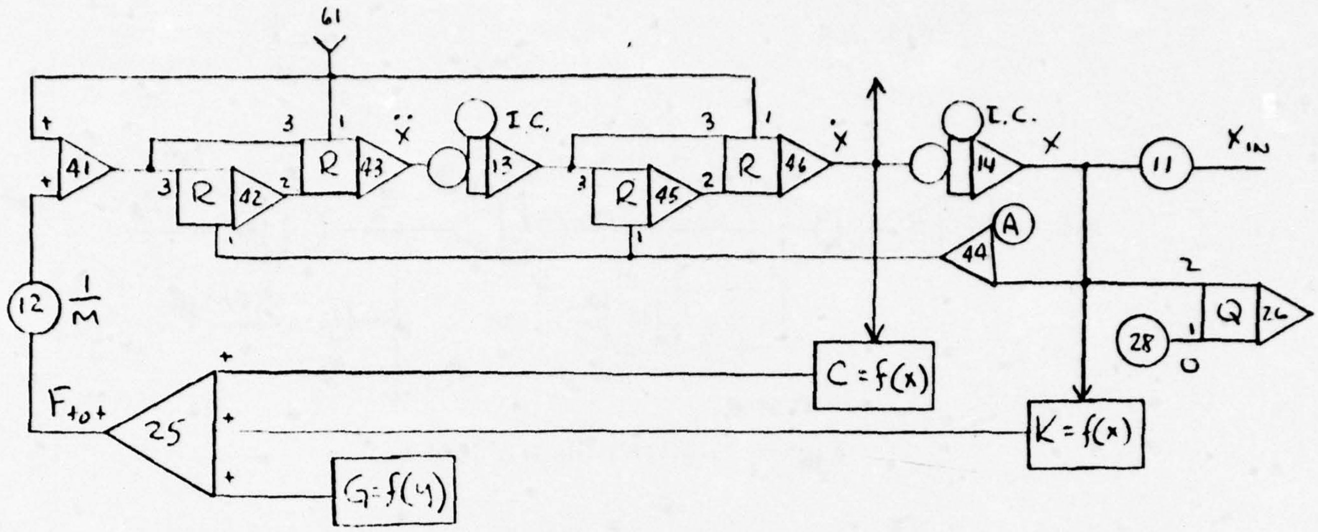


Figure F-3. Pin Motion.

Equations Simulated:

M X + C X + K X + G = f(t)

Operation (Figure F-3):

This is the generalized equation for damped harmonic motion. The forcing function is projectile acceleration, obtained from Block 61. It is summed with the interior accelerations in adder Blocker 41, and successively integrated in Blocks 13 and 14 to obtain velocity and displacement. C, K, and G are the internal forces (usually considered as viscous, spring, friction, etc.). In this system they are non-linear and discontinuous and are computed as outlined elsewhere. They are summed in Block 25 (signs may be changed to observe observe the sign convention used in computation) and multiplied by the reciprocal mass in Block 12 to yield acceleration.

The chain of relays, Blocks 42 and 43, and 45 and 46, switched by Lock 61 and the offset, Block 44, whose output equals its input plus P_1, facilitates operation of the program during some time periods and does not enter into the equation of motion. The quit, Block 26, terminates calculations when Input 2<Input 1. For those who like to think in inches, Block 11 provides this.

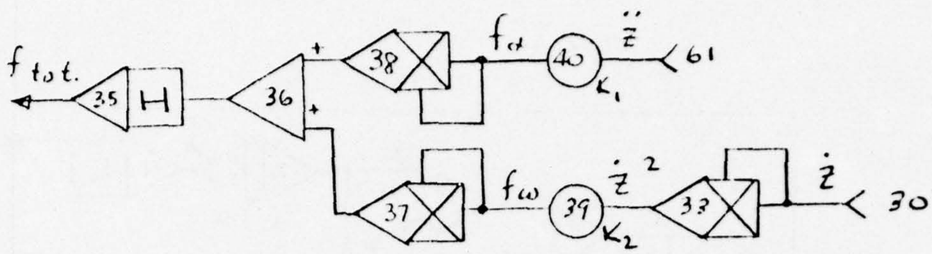


Figure F-4. Sliding (O-Ring) Friction.

Equations Simulated:

1. $f\alpha = M\mu r\left(\frac{2\pi}{Td}\right)\ddot{Z}$

2. $f\omega = M\mu r\left(\frac{2\pi}{Td}\right)^2 \dot{Z}^2$

3. $f_{tot} = (f\alpha^2 + f\omega^2)$

Notation:

μ = Coefficient of Friction

r = Displacement of spin axis

T = Twist of rifling

d = Caliber of gun

f = Friction

Operation (Figure F-4):

In this system the setback pin is not concident with the spin axis of the projectile so that the angular motion causes two frictional components which will retard the motion of the pin. $f\alpha$ is caused by angular acceleration and $f\omega$ is caused by spin rate. Block 40 multiplies projectile acceleration by the constant factors of Equation 1. The multiplier Block 33 multiplies velocity by itself, yielding $\dot{Z}^2$, which is then multiplied by K_2. Since $f\alpha$ acts tangentially and $f\omega$ acts radially, they are each squared in Blocks 37 and 38, summed in Block 36, and the square foot extracted by the Half Power Block 35 to yield the vectorial friction force.

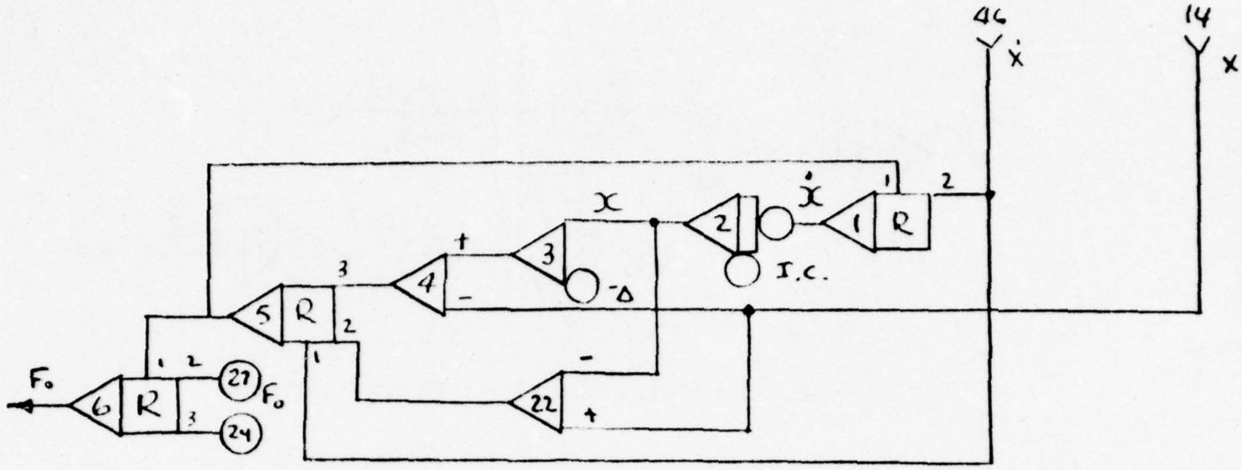


Figure F-5. O-Ring Friction.

Equations Simulated:

$\dot{\chi} = 0$ for $(\chi - \Delta) < X < \chi$	χ = O-ring position
$\dot{\chi} = \dot{X}$ for $X = \chi$ and $\dot{X} > 0$	Δ = R-ring slack
$\chi = \dot{X}$ for $X = (\chi - \Delta)$ and $\dot{X} < 0$	F_O = O-ring friction

Operation (Figure F-5):

The setback pin has an O-ring gland operating within cylinder as shown in Figure F-6. As the pin moves from $X = 0$ toward Xmax ($\dot{X} > 0$) it can travel Δ before the O-ring begins to move. Any subsequent reversal of motion ($\dot{X} < 0$) will also allow the pin to move Δ without moving the O-ring. O-ring friction is present only while the O-ring is moving. The Block 1 relay sets $\dot{\chi} = \dot{X}$ when the O-ring is in contact with the pin, so that χ moves in step with X. χ and $(\chi - \Delta)$ are compared with X to test this condition at every integration. Block 6 is switched under the same conditions to output either F_O or 0.

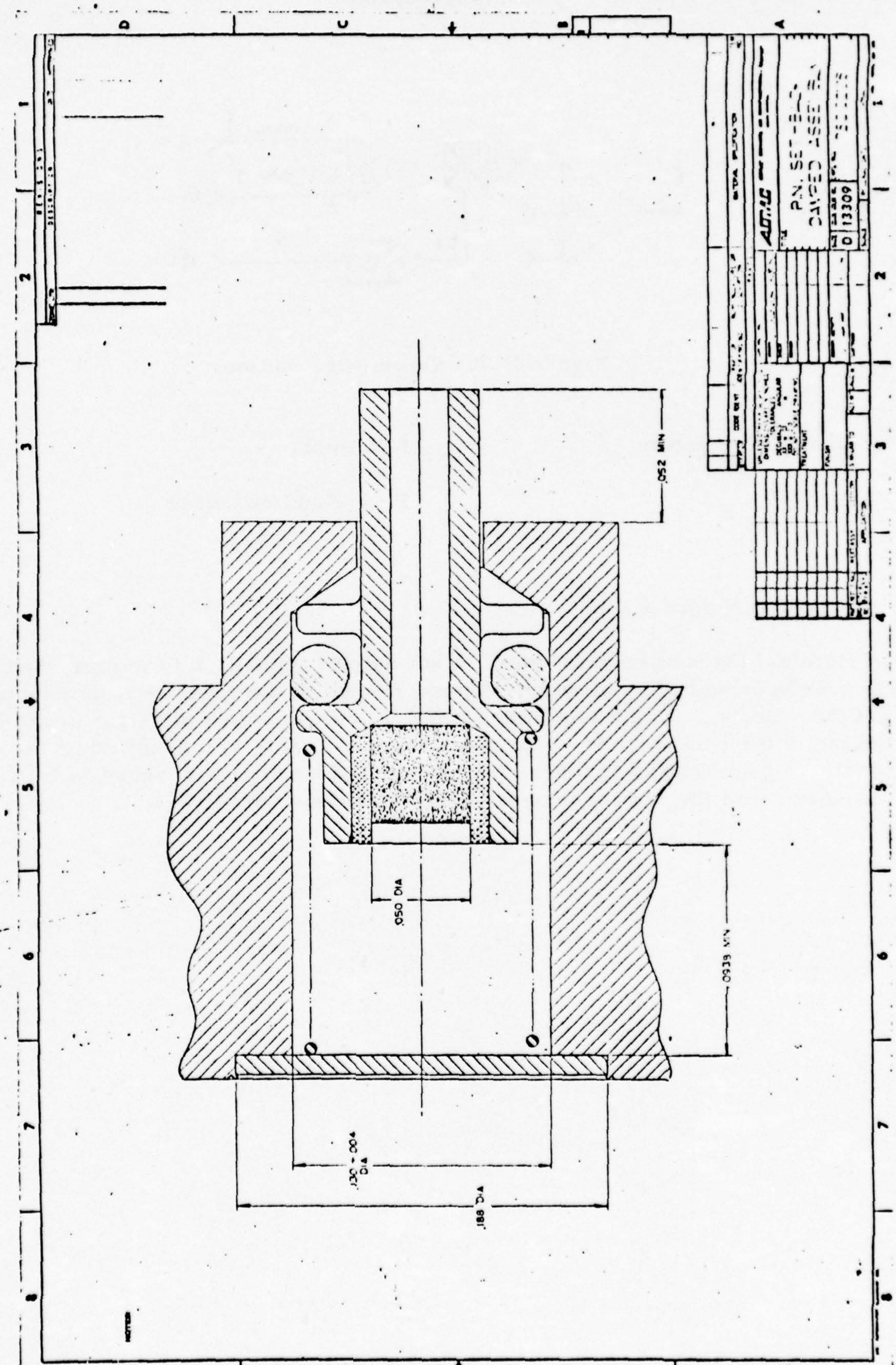


Figure F-6. Damped Setback Pin Assembly.

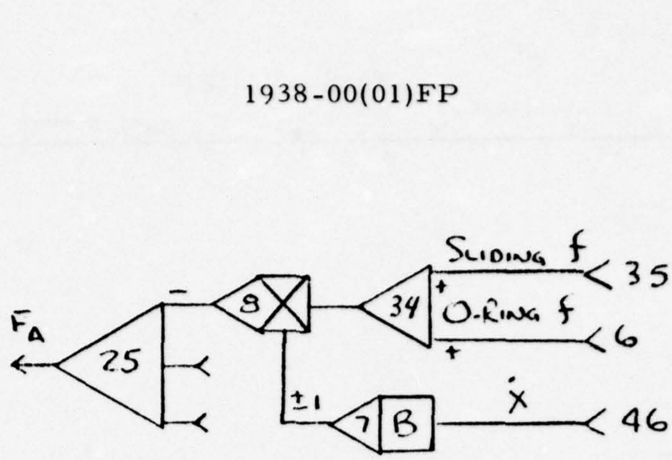


Figure F-7. Combined Friction.

Equation Simulated:

$$F_A = \frac{\dot{X}}{(\dot{X})} F$$

Notation:

F = Friction Force

Operation (Figure F-7):

Frictional forces are considered to act only in opposition to motion, hence they are independent of position and dependent only to the sign, not the magnitude of the velocity. The Bang-Bang, Block 7, has an output of -1 for negative input, 0 for 0 input, and +1 for positive input. This is multiplied by the summation of the frictional forces (Block 34) and its sign is changed in Block 25 to agree with the sign convention used to indicate opposition.

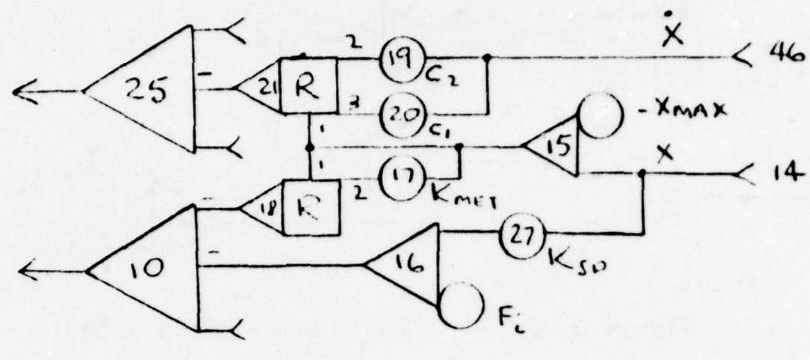


Figure F-8. Spring Force and Viscous Damping.

Equations Simulated:

$$F_{sp} = F_o + K_{sp} \cdot X + K_{met} (X - Xmax)$$

$$C = C_1 \cdot \dot{X} \text{ for } X < Xmax$$

$$= C_2 \cdot \dot{X} \text{ for } X > Xmax$$

Notation:

K = Spring rate

C = Damping coefficient

Operation (Figure F-8):

As the pin moves towards its stop (increasing X) the return spring is compressed, giving increasing force. Contact with the stop is equivalent to contact with another spring having an extremely high spring rate. Viscous damping forces, which are proportional to $\sqrt{Km}$, also change at that point. Relay, Block 18 is switched at Xmax to add the spring rate of the metallic stop. Relay 21 is also switched to allow for the differing conditions.

NOTE: There is also an aerodynamic damping term proportional to $\dot{X}^2$. For the small physical size and low velocities encountered in this simulation it may be ignored without significant error, especially because the major, non-linear aerodynamic force is calculated as a function of air flow as shown in the following section.

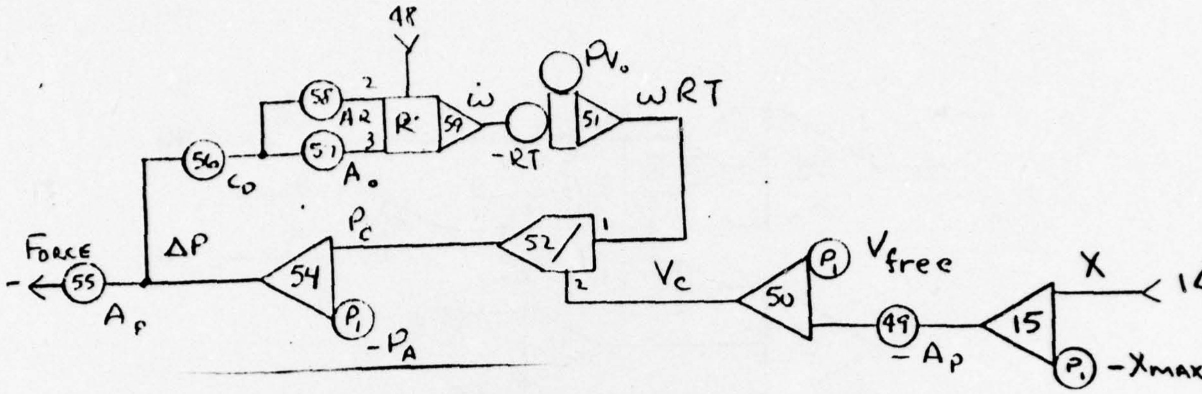


Figure F-9. Air Flow and Equation of State.

Equations Simulated:

$PV = wRT$	P = pressure	R = gas constant
$\dot{\omega} = C_D \cdot A_T \cdot \Delta P$	V = volume	T = abs. temp
$F = \Delta P \cdot A_p$	w = weight of gas	A_T = equiv. area of throat
	$C_D \approx$ disch. coeff.	A_p = area of pin

Operation (Figure F-9):

The setback pin (See Figure F-6) has cutouts through the forward face of the O-ring groove, allowing leakage while the pin moves rearward. The O-ring seals during forward motion, forcing air to pass through the sintered metal plug. As the flow through the restrictors is proportional to ΔP (Mfg's data) it could be replaced by a simple orifice of known (small) area having the same flow rate. C_D is a function of the thermodynamic properties of the gas only. For low pressures, air may be considered to behave like a perfect gas.

The <u>divider,</u> Block 52, divides Input 1, wRT, by Input 2, the instantaneous chamber volume, giving the chamber pressure. Since the front of the pin is exposed to atmospheric pressure, Block 54 yields ΔP. The relay, Block 59, is switched by -X so that the O-ring leakage area is used for rearward motion and the restrictor equivalent area is used for forward motion, having $\dot{\omega}$ as its output. This is integrated, multiplied by -RT, and added to the initial PV in Block 51 to yield total wRT. ΔP is also multiplied by the pin area in Block 55 to give the force due to air presssure.

Fortran IV
Program Listing

```
PAGE   1

// JOB    0001

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        0001        0001        0000

V2 M10   ACTUAL  8K  CONFIG  8K

// FOR
* LIST ALL
* ARITHMETIC TRACE
* TRANSFER TRACE
* EXTENDED PRECISION
* ONE WORD INTEGERS
* IOCS(CARD,1132 PRINTER)
      REAL INTGL,MEW,K,L
1000  FORMAT(8F10.0)
      READ(2,1000)P1,A,ASTAR,R,L,VO,XMAX
      READ(2,1000)DELT,Z
2     READ(2,1000)FO,K,TEE,C3
      IF(TEE)999,999,3
3     WRITE(3,1005)
1005  FORMAT(1H1,T15,'T(SEC)',T34,'X(IN.)',T50,'P2(PSI)')
      INTGL=0.0
      T=0.0
      C1=(FO/K-(P1*A)/K)
      C2=(C1*VO)/A+(P1*VO)/K
      MEW=2.27E-08*((TEE*01.5)/(TEE+180.))
      C4=(C3*ASTAR*R*TEE)/(MEW*L)
      C5=(C1-VO/A)
      Q=((C1-VO/A)**2.)+(4.*C2)
      X=0.5*(C1-VO/A)+0.5*SQRT(Q)
      V1=(VO+A*X)
      P2=(P1*VO)/(VO+A*X)
      FX=X*12.
      P22=P2/144.
      WRITE(3,1009)T,FX,P22
1009  FORMAT(T15,F10.3,T34,F7.4,T49,F7.3)
20    T=T+DELT

      INTGL=INTGL+(P3-P2)*DELT
      P3=((P1*VO)+(C4*INTGL))/(VO+A*X)
      V3=VO+A*X

PAGE   2

      C6=(P3*V1)/K+(C1*VO)/A
      QQ=(C5**2.)+(4.*C6)
      X=.5*C5+0.5*SQRT(QQ)
      V1=(VO+A*X)
      P2=(P3*V3)/V1
      FX=X*12.
      P22=P2/144.
      TT=T/Z+.00002
      ITT=TT
      ZZ=TT-ITT
      IF(ZZ-.001)99,99,100
99    WRITE(3,1010)T,FX,P22
1010  FORMAT(T15,F10.3,T34,F7.4,T49,F7.3)
100   IF(X-XMAX)20,500,500
500   CONTINUE
      WRITE(3,1010)T,FX,P22
      GO TO 2
999   CONTINUE
      STOP
      END
VARIABLE ALLOCATIONS
  INTGL(R )=0000       MEW(R )=0003        K(R )=0006        L(R )=0009        P1(R )=000C        A(R )=000F
  ASTAR(R )=0012         R(R )=0015       VO(R )=0018     XMAX(R )=001B      DELT(R )=001E        Z(R )=0021
     FO(R )=0024       TEE(R )=0027       C3(R )=002A        T(R )=002D        C1(R )=0030       C2(R )=0033
     C4(R )=0036        C5(R )=0039        Q(R )=003C        X(R )=003F        V1(R )=0042       P2(R )=0045
     FX(R )=0048       P22(R )=0048       P3(R )=004E       V3(R )=0051        C6(R )=0054       QQ(R )=0057
     TT(R )=005A        ZZ(R )=005D      ITT(I )=0066

STATEMENT ALLOCATIONS
 1000 =008C  1005 =008F  1009 =00A2  1010 =00A9  2    =00DF  3    =00EF  20   =019C  99   =0233  100  =0230  500  =0244
 999  =0250

FEATURES SUPPORTED
 TRANSFER TRACE
 ARITHMETIC TRACE
 ONE WORD INTEGERS
 EXTENDED PRECISION
 IOCS

CALLED SUBPROGRAMS
 FSQRT  EAXR   EADD   ESUB   EMPY   EDIV   ELD    ESTO   ESBR   EDVR   SEAR   SIAR   IFIX   FLOAT  SEIF
 CARDZ  PRNTZ  SRED   SWRT   SCOMP  SFIO   SIOF   STOP

PAGE   3

REAL CONSTANTS
  .0000000000E 00=006B   .2270000000E-07=006B   .1500000000E 01=006E   .1800000000E 03=0071   .2000000000E 01=0074
  .4000000000E 01=0077   .9000000000E 00=007A   .1200000000E 02=007D   .1440000000E 03=0080   .2000000000E-04=0083
  .1000000000E-02=0086

INTEGER CONSTANTS
     2=0089      3=008A    0=008B

CORE REQUIREMENTS FOR
 COMMON      0  VARIABLES    104  PROGRAM    490

END OF COMPILATION
```

Appendix G

ANALYSIS OF 200-FPS SAFETY REQUIREMENT

Consider this imaginary situation: A young fuze designer sets out to design an artillery fuze which, among other things, must be safe after a 40-ft drop. Deciding to use setback as an arming parameter, he comes up with a concept that will arm only if the acceleration-time curve of actual firing is closely duplicated. He takes it in and describes it to his boss:

"But how," his boss inquires, "do you know it won't arm following 40-ft drop?"

"Because," the young engineer replies, "it will arm only under actual firing conditions."

"But how do you know," the boss persists, "that you can't accidentally reproduce the acceleration-time pattern of actual firing by dropping it 40 ft?"

This gives the young engineer pause. It certainly seems unlikely that this could happen, but obviously we cannot base a safety feature on an intuitive feel that something is "unlikely." The more he considers the type of media upon which a dropped artillery shell might impact, the more he is convinced that it is impossible to draw all possible accidental acceleration-time curves.

Finally it comes to him. The answer to the boss's question lies not in considering the shape of the curve, but in considering the area under the curve V, the change in velocity imparted to the object experiencing the acceleration. An object dropped from 40 ft has an impact velocity given by

$$V_i = \sqrt{2\ gh} = \sqrt{2 \times 32.2 \times 40} = 50.75 \text{ fps}$$

If the impact were perfectly elastic, the object would rebound with the same velocity in the upward direction. Thus the total change in velocity produced by the impact is

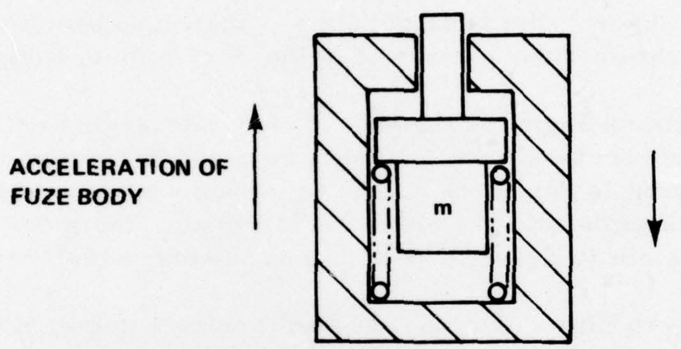
$$V = 2\ V_i = 101.5 \text{ fps}$$

If one added a safety factor and required that the fuze not arm under a V of 200 fps, then it would be safe from a drop of

$$h = \frac{(200)^2}{2\,g} = 621.1 \text{ ft}$$

It is clear, then, that requiring that the fuze experience a velocity change of at least 200 fps will provide adequate safety.

Now consider whether a simple spring-mass system can be used to discriminate between intentional firing and accidental drop. During the impact following a drop, the mass will tend to continue moving downward, compressing the spring, while the fuze body surrounding the mass rebounds. The mass will thus do work on the spring. The total energy continued in the mass is $1/2\ MV_i^2$, where V_i is the impact velocity. However, since the spring and the reference system are moving, this must be considered. Let us imagine, then, what an observer riding along the fuze body, but unaware of any fuze body acceleration, would see.



If the impact were very soft, the spring would not be compressed at all (beyond its initial compression) and the observer would see no firing pin motion. He would attribute no kinetic energy to the setback pin. As the impact got firmer, the setback pin would achieve some velocity as seen by the observer. Now imagine that the impact became extremely firm, so that the observer himself changed almost instantaneously from V_i in the downward direction to V_i in the upward direction. The change is so sudden that the motion of the firing pin is unaffected during the change. Then, just after the change, the observer would think that the firing pin velocity was $2V_i$ in the downward direction, and that, therefore, its true kinetic energy was $(1/2M)\ (2V_i)^2 = 1/2M\,(\Delta V)^2$. Since the setback pin would compress the spring accordingly, this instantaneous velocity reversal would cause the maximum possible spring compression. We can say, then, that the maximum possible spring compression during accidental drop is given by

$$1/2k\ X_m^2 + Fo\ X_m = 1/2\ m\ (\Delta V)^2$$

where

K = spring rate, lb/ft

X_m = maximum setback pin movement, ft

F_o = initial spring force, lb

m = mass of setback pin + 1/2 mass of spring, slug

V = velocity change of fuze, fps

The present design has these parameters:

K_{max} = 3.960 lb/ft

X_{max} = 0.094/12 = 0.00783 ft

F_{omax} = 0.110 lb

m = 0.00001071 slug

Solving for ΔV, we get

$$\Delta V = \left[\frac{1/2 K X_{max}^2 + F_o X_{max}}{1/2 m}\right]^{1/2}$$

There are only four ways to increase ΔV:

Increase K

Increase X_{max}

Increase F_o

Decrease m, damp the pin during retraction cycle.

But these variables are not entirely independent. First of all, X_{max} is fixed by the fuze design and so cannot be changed. The equation for ΔV is, then

$$\Delta V = \left[\frac{0.00006130\ K + 0.01566\ F_o}{m}\right]^{1/2}$$

Thus, within the constraints imposed upon the system, a ΔV of 12.3 fps is all that can be achieved. The actual system, at the extreme end of the tolerances, exceeds this slightly because, at those extremes, a slightly greater than 300g system exists.

The fact is that small spring-mass systems cannot visually be made into effective arming discriminators, which is the reason that they are not used more frequently.

There is a further requirement: the setback pin must move back during firing and be held back until the acceleration of the projectile falls to some level. Picatinny has suggested that 500g would be a suitable level. In that case, we would have, when the setback pin is fully withdrawn and bottomed out (if friction is ignored):

$$F_o + KX_{max} = 500 \text{ mg}$$

However, we have found that a 500g spring causes too much rebound after setback is over, with the pin bouncing back by about 0.054 in. before the vacuum stops it. With a 300g spring, however, the rebound before the vacuum stops it is about 0.018 in., which is bearable. Let us say, then, that (again *ignoring friction*)

$$F_o + KX_{max} = 300 \text{ mg} \tag{1}$$

or

$$\frac{F_o}{m} + 0.00783\frac{K}{m} = 9660 \tag{2}$$

Rewriting Equation 1 gives

$$0.01566\frac{F_o}{m} + 0.000006130\frac{K}{m} = \Delta V^2 \tag{3}$$

Dividing through by 0.01566 gives

$$\frac{F_o}{m} + 0.003915\frac{K}{m} = \frac{(\Delta V)^2}{0.01566} \tag{4}$$

Subtracting Equation 4 from Equation 2 gives

$$0.00744\frac{K}{m} = 9660 - \frac{(\Delta V)^2}{0.01566}$$

Since K/m cannot become negative, there is a clear limit to the value of K/m. Note that K/m, which is time square of the natural frequency of the system, must go down as the desired ΔV is increased. Solving for the maximum possible value of ΔV which will prevent K/m from going negative gives

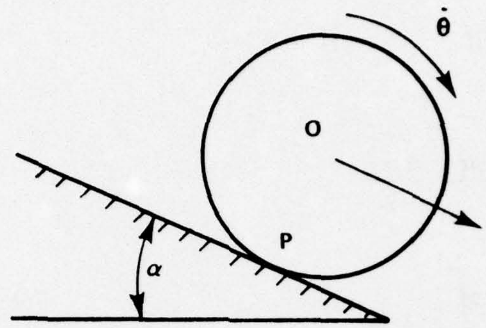
$$V = \sqrt{(9660)\,(0.01566)} = 12.3 \text{ fps}$$

Appendix H

ANALYSIS OF A PROJECTILE ROLLING DOWN INCLINED PLANE

The analysis that follows is one of several situations that might take place on a projectile during handling.

Projectile rolling down an inclined plane:



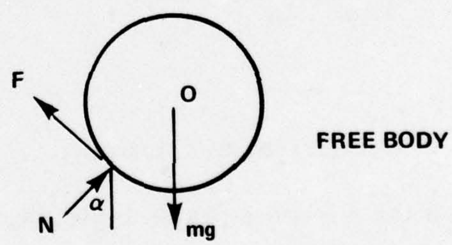
$$M = I\ddot{\theta} \quad \text{Neglect rolling friction}$$

where

M = applied moment

I = polar moment of inertia $= \frac{1}{2}mR^2$

$\ddot{\theta}$ = angular acceleration



M = FR or $F = \frac{M}{R}$ and substituting

$$F = \frac{1}{2} mR\ddot{\theta} \tag{1}$$

Linear acceleration of the center of mass is $R\ddot{\theta}$ and is directed down the plane:

$$mg \sin\alpha - F = mR\ddot{\theta} \tag{2}$$

Substituting Equation 1 into Equation 2

$$mg \sin = \frac{3}{2} mR\ddot{\theta} \tag{3}$$

or

$$\ddot{\theta} = \frac{2g \sin\alpha}{3R} = \frac{d\omega}{dt}$$

$$\int_0^{\omega} d\omega = \frac{2g \sin\alpha}{3R}\int_0^{t} dt$$

$$t = \frac{\omega 3R}{2g \sin\alpha} \tag{4}$$

This is the time required for the projectile to reach a specified spin rate.

The maximum angle at which an inclined plane can be tilted without any slippage occurring between cylinder and plane* is given by

$$\alpha = \mathrm{Tan}^{-1} 3\mu$$

where

$$\mu = \text{coefficient of friction}$$

Assuming $\mu = 0.8$ the inclined plane angle, α, becomes 67.4°.

The S&A device is safe to rotate up to a spin rate of 1100 rpm (See Picatinny Drawing 9294833, Note 4). The smallest projectile that this S&A device is used in is 105mm, or 4.13 in. diameter.

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*From Cox, G.N., and W.G. Plumtree, Engineering Mechanics, Van Nostrand Co., Inc., Princeton, N.J., 2nd Ed. (1956), p. 304.

Substituting all known values into Equation 4 gives a maximum permissible delay time of

$$t = \frac{\left(\frac{1100 \times 2\pi}{60}\right)(3)\left(\frac{4.13}{2 \times 12}\right)}{2g \sin 67.4} = \underline{\underline{1.0002 \text{ sec}}}$$

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